SPACEPORT CONCEPT OF OPERATIONS

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November 2004

FUTURE INTERAGENCY RANGE AND SPACEPORT TECHNOLOGIES

FIRST

Reducing the Cost of Sustained Operations Through Technology Infusion

SPACEPORT CONCEPT OF OPERATIONS

A Vision For Spaceports and Future Space Transportation Systems

Future Interagency Range and Spaceport Technologies

May 2004

FOREWORD

The Future Interagency Range and Spaceport Technologies (FIRST) initiative is a partnership and interagency working group of NASA, the Department of Defense (Air Force Space Command and Office of the Secretary of Defense), and the Federal Aviation Administration. The partnership was established to guide transformation of U.S. ground and space launch operations toward a single, integrated national "system" of space transportation systems that enables low-cost, routine, responsive and safe access to space for a variety of applications and markets through technology infusion. This multi-agency consortium is formulating plans to create a national program office that will coordinate individual agency plans to produce an integrated national space transportation system infrastructure comprised of spaceports, ranges, and space and air traffic management systems.

A set of concepts of operations, or CONOPS, has been produced to articulate a cohesive interagency vision for this future space transportation system in support of FIRST program formulation efforts. These concepts are intended to guide and support the coordinated development of technologies that allow multiple launch vehicle architectures and missions to be supported by the same ground and launch systems without significant modification. These documents reflect the interests of the partners in the working group, and are not intended to imply final approval or policy of any of the participating agencies.

May 2004

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EXECUTIVE SUMMARY

In recognition of the national importance of routine, responsive, reliable and low cost access to space, NASA's Kennedy Space Center (NASA KSC), the DoD Director of Operational Test and Evaluation (DOT&E), Air Force Space Command (AFSPC), and FAA's Associate Administrator for Commercial Space Transportation (FAA/AST) have partnered under the Future Interagency Range and Spaceport Technologies (FIRST) effort to jointly plan for cooperative development of technologies to enable the development of future spaceport and range systems and capabilities.

PURPOSE

The purpose of this concept of operations (CONOPS) is to provide a common national vision for this consortium with regard to the architecture and operation of a Future Space Transportation System (FSTS). Spaceports form the foundation from which all future space missions will be launched. Specifically, this CONOPS describes how an evolved system of spaceports incorporating advanced technologies enables and supports a variety of civil, commercial and national security space launch operations and flight test activities when and where needed around the world.

This CONOPS describes future spaceport operations and areas for spaceport technology advancement and development. The intent is to enable concept approval prior to moving into technology gap assessments as well as business case, return on investment, and value proposition analyses.

TIME FRAMES

U.S. space transportation operations are expected to evolve through a series of spiral development steps. These steps will be implemented through three planning eras as identified by the FIRST program; the Transformation Era, Responsive Space Launch and Human Exploration Era and the Mass Public Space Transportation **(See Figure ES-1)**.

The first, or current, era is characterized by transformation. Transformation refers to fundamental change involving advanced technologies to enable new concepts of operation that are implemented and institutionalized through new policies, organizations, architectures, and economic and business models. These changes will initiate the fundamental shift away from vehicle-unique infrastructure, establishing the spiral development path for technology advances needed to support future missions.

Such future missions, as noted in **Figure ES-1**, characterize the second, or Responsive Space Launch and Human Exploration Era. This era is poised to begin in the next decade. The third era, Mass Public Space Transportation, is envisioned to begin when the economics and technology of space travel align with the demands of a mass market. It is characterized by safe, routine, affordable commercial space travel—much like air travel today. In this era, it is anticipated that space transportation will become an integral part of the global mass public transportation system of the future.

In formulating and planning the FIRST program, three eras are addressed.

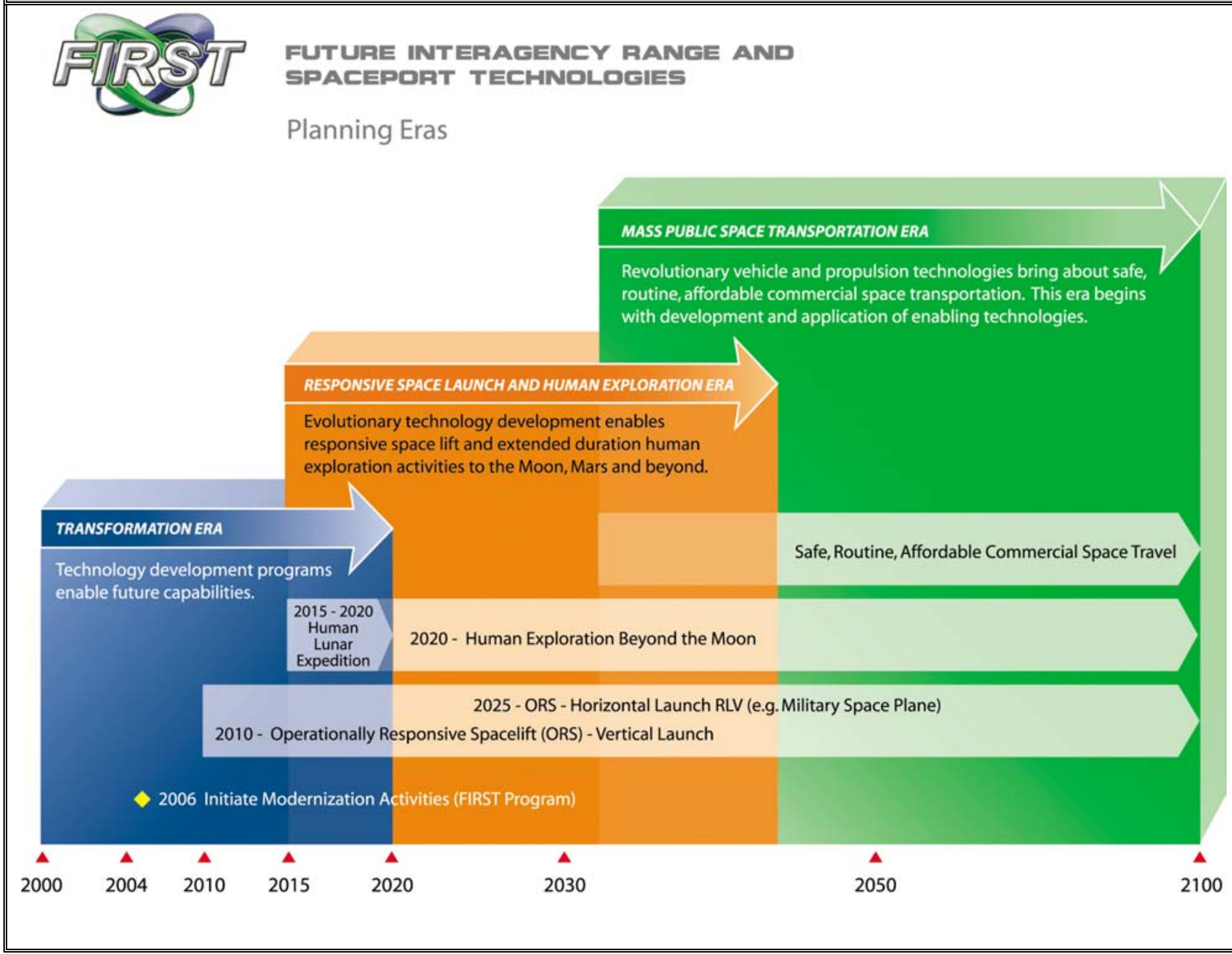


Figure ES-1 FIRST Program Planning Eras

The most significant difference between the first two eras and the concept envisioned in the third era is the realization of spaceport efficiencies that drive mass market development and integration of aerospace industry market segments with traditional core economy markets including the transportation, communications and tourism industries, among others. This integration will promote multiplier effects for FIRST Program benefits to drive new economies of scale in the global marketplace.

PRIMARY ASSUMPTIONS

The Spaceport CONOPS is based on a few primary assumptions, including:

- Future Spaceports will need to support three separate and distinct launch modes: vertical, vertical super-heavy, and horizontal. The proportion of facilities supporting the three launch modes will shift through the planning eras with the evolution of vehicle technology.

- Horizontal, quick turnaround vehicles will not be processed in the same facilities as vertically launched expendables, even if the vertical launch vehicles are processed horizontally.

- Similar horizontally operating reusable flight vehicles will be processed within the same spaceport facilities. It is also assumed it will be acceptable to military operations for military vehicles to be processed through common maintenance/repair/service facilities, which would also simultaneously service similar non-military civil or commercial vehicles.

- Shared spaceport operations will be structured to facilitate timely access to space for all users without unnecessary delays or restrictions that would adversely affect their business plan.

- Spaceport management procedures will be streamlined to facilitate responsive scheduling and launch.

- The introduction of hypersonic transport vehicles for mass public transportation will be economically viable only if/when hypersonic vehicles can be assimilated into the evolved worldwide airport network (i.e. a network of Commercial Transportation Centers). Conversely, the development of a separate network of spaceports requiring connective infrastructure from remote locations to the evolved airport network (and related population centers) in order to address incompatible hypersonic vehicle operating characteristics would not be economically viable.

- It is assumed future suborbital and orbital reusable launch vehicles will be so reliable as to be able to fly over populated areas without risks to public safety above the currently acceptable levels associated with commercial air traffic today.

DESCRIPTION OF SPACEPORT ARCHITECTURE

Spaceport Functions

Future spaceport architecture must accommodate the same types of test and operational missions that are supported by today's spaceports, plus a variety of additional missions as described in the FIRST Needs Assessment. The primary functions of future spaceports include:

<u>Flight Element Operations</u>

Flight element operations addresses all activities associated with receipt, acceptance, handling, assembly and checkout of new flight vehicles and components shipped to the spaceport for launch, and handling, disassembly, processing and return for service or disposition of all launch vehicles and components returning to the spaceport at the conclusion of a launch or mission.

Payload Element Operations

Payload element operations address all activities associated with receiving, staging, assembling and preparing up-payloads for integration with the launch/flight vehicle and intake of down-payloads and payload infrastructure returned from space and the subsequent disassembly, staging and shipping of payloads and components. The spaceport base operating model envisions common payload processing operations serving most all programs and vehicle types.

Integrated Operations

Integrated operations refer to mission activities related to the assembly of vehicle and payload elements, preparation for and subsequent vehicle launch, flight and mission activities, and return and recovery of vehicle and payload elements.

Flight and Ground Traffic Control and Safety Operations

The spaceport will maintain operations and equipment necessary to maintain safe operating conditions at the spaceport.

Enabling Operations

Enabling operations are management, operational, facility and maintenance activities related to the overall spaceport infrastructure that supports all mission and program activities at a spaceport.

SPACEPORT OPERATIONS LIFE CYCLE

For the purpose of developing a common framework for discussing spaceport and range CONOPS the Spaceport Operations Life Cycle was developed **(Figure ES-2)**.The Spaceport Operations Life Cycle consists of six sequential operational phases associated with space launch and flight test missions, supported by Enabling Functions. The CONOPS presents spaceport functions and subfunctions mapped to the Spaceport Operations Life Cycle. To support the identified existing and future missions, spaceports must be configured to provide the required services and infrastructure to accommodate activities within each phase.

Spaceport operations are typically conducted in six sequential phases.

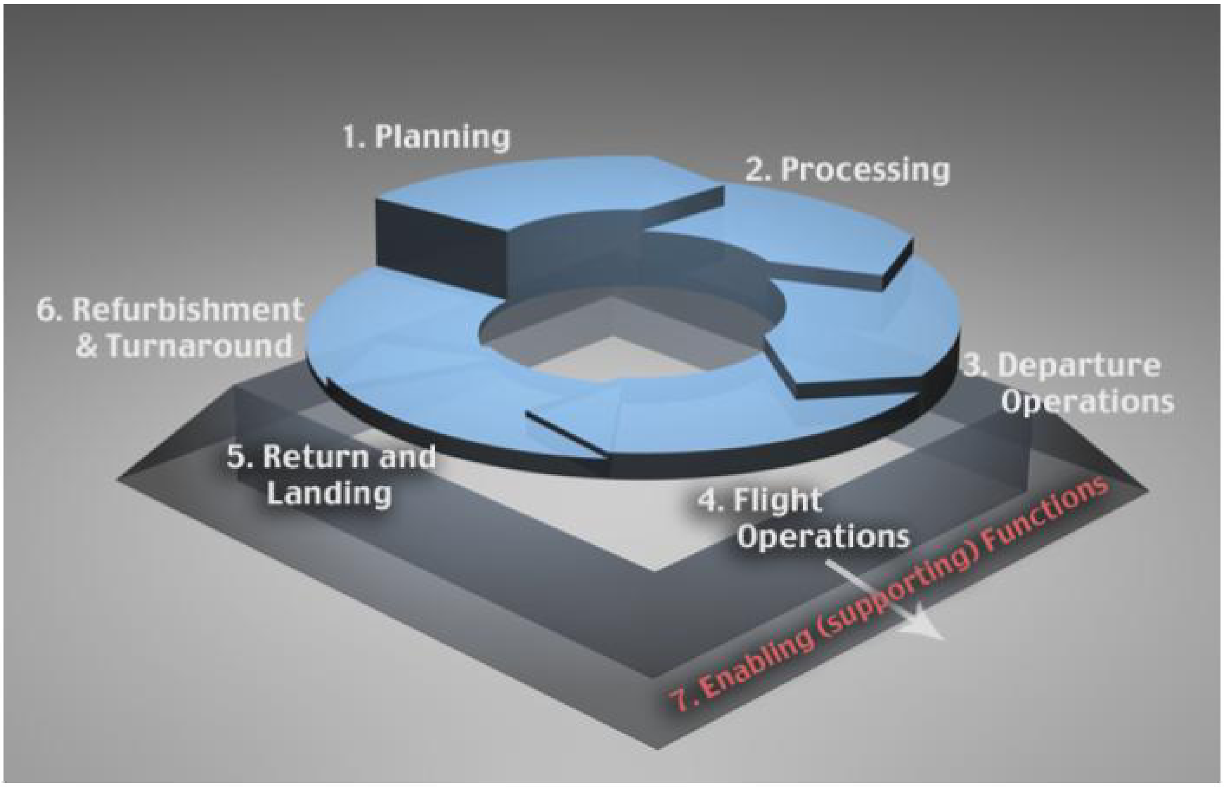


Figure ES-2 Spaceport Operations Life Cycle

REFERENCE MISSION CONFIGURATIONS

To address all identified existing and future spaceport user needs, a database of reference mission configurations was developed that outlined the nature and characteristics of numerous existing and planned future missions. After development of the complete list, missions with similar or identical operational activities and configurations were grouped together. These groups represent the number of different operational configurations spaceport infrastructure will be required to support.

OPERATIONAL FLOW MODELS

Each group of operational configurations was then analyzed to identify all required spaceport functions within the context of the Operations Life Cycle to develop a flow diagram, or Operational Flow Model, depicting the sequenced flow of spaceport functional activities required to facilitate the mission operations defined by the group. Fifteen separate Operational Flow Models were developed as a result of the grouping and subsequent analysis of the reference mission configurations. The models show the sequence of activities necessary to accomplish and support the reference missions attributed to each model, and are presented in sequence corresponding to the Operations Life Cycle Phases. The defined Spaceport Operational Flow Models include:

Model A	Vertical Launch Expendable Clean Pad – Minimal On-Site Infrastructure
Model B	Vertical Launch Expendable – Payload to Orbit / Beyond Orbit
Model C	Vertical Launch Expendable – Payload (Weapons) to Target
Model D	Vertical Launch Partially Reusable – Payload to Orbit – Super Heavy Lift
Model E	Vertical Launch Partially Reusable – Crew / Passengers – Orbital
Model F	Vertical launch Horizontal Recovery – (Non-Crewed) - Payload to Orbit
Model G	Vertical launch Horizontal Recovery – Crew / Payload to Orbit / Beyond Orbit – Exploration Missions
Model H	Vertical launch Horizontal Recovery – Crew / Payload Beyond Orbit – Exploration Missions
Model I	Vertical Launch Vertical or Horizontal Recovery – Crew / Passengers – Suborbital – Low Volume Space Tourism
Model J	Air Launch Horizontal Recovery – Aircraft First Stage – Payload to Orbit
Model K	Horizontal Launch Horizontal Recovery – Payload to Orbit and On-Orbit Asset Services and Recovery
Model L	Horizontal Launch Horizontal Recovery – Payload to Target (Weapons)
Model M	Horizontal Launch Horizontal Recovery – Crew/Passengers Suborbital–High Volume–Mass Public Space Transportation
Model N	Horizontal Launch Horizontal Recovery – Crew / Passengers Suborbital – Low Volume – Space Tourism
Model O	Horizontal Launch Horizontal Recovery – Crew / Passengers / Payload to Orbit

OPERATIONAL FLOW MODELS BY PLANNING ERA

Operational Flow Models A through O represent current and future mission configurations spanning the Transformation, Responsive Space Launch and Human Exploration and Mass Public Space Transportation Eras, as presented in Section 2. **Figure ES-3** presents the anticipated timing of each Operational Flow Model with respect to the Planning Eras.

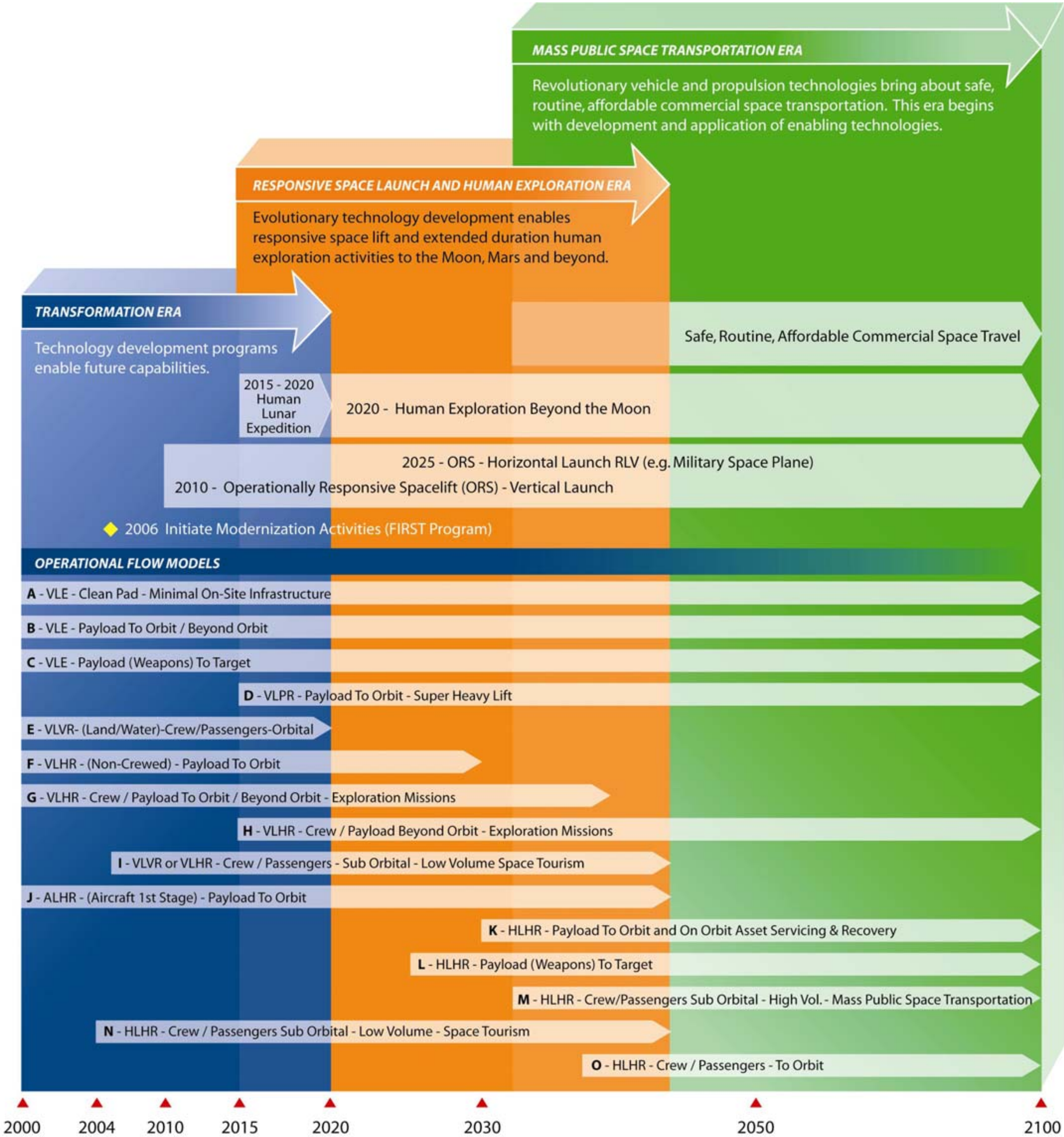


Figure ES-3 Operational Flow Models by Planning Era

Next, each reference mission was assigned to a corresponding Design Reference Mission (DRM) category.

DESIGN REFERENCE MISSION CATEGORIES

A DRM category refers to the grouping of operational characteristics pertaining to all reference missions. Three DRM categories have been identified to describe the operational characteristics of the reference mission configurations.

- **Routine** - Routine DRMs are scheduled, occur on a planned basis and represent the majority of all spaceport mission operations. Representative examples of routine missions include payload launch to orbit or deep space, launch of an exploration mission and a space tourism flight.

- **Responsive** – Responsive DRMs are unscheduled and occur as the result of the occurrence of an event requiring a space launch response. Representative examples of responsive missions include launch of a missile defense system vehicle, an ORS-PGS launch, launch of a rescue mission, and emergency on-orbit repair or service.

- **Testing & Evaluation** – Testing & evaluation DRMs occur at specialized spaceport locations where new vehicle and component or system development is a part of spaceport activities. Representative examples of testing & evaluation activities include powered or drop flight testing of a new vehicle airframe or propulsion system, static testing of propulsion systems or components or first launch of a new vertical launch vehicle.

Consideration of a reference mission's DRM category is necessary in determining a spaceport's required operational characteristics. Each Operational Flow Model, which evolved from and represents multiple reference mission configurations, must also accommodate the operational requirements associated with one or more DRM categories.

SPACEPORT OPERATIONAL MODELS

The goal in identifying all potential reference missions and consideration of DRM categories was the creation of one or more activity flow diagrams, or Spaceport Operational Models, that define the operational characteristics required of a spaceport to meet all related reference mission configuration and DRM category operational requirements. The following Spaceport Building Blocks diagram, **Figure ES-4**, depicts the analytical process used to define the criteria and evaluate the relevant data in developing Spaceport Operational Models to meet the operational needs of an evolving Future Space Transportation System (FSTS).

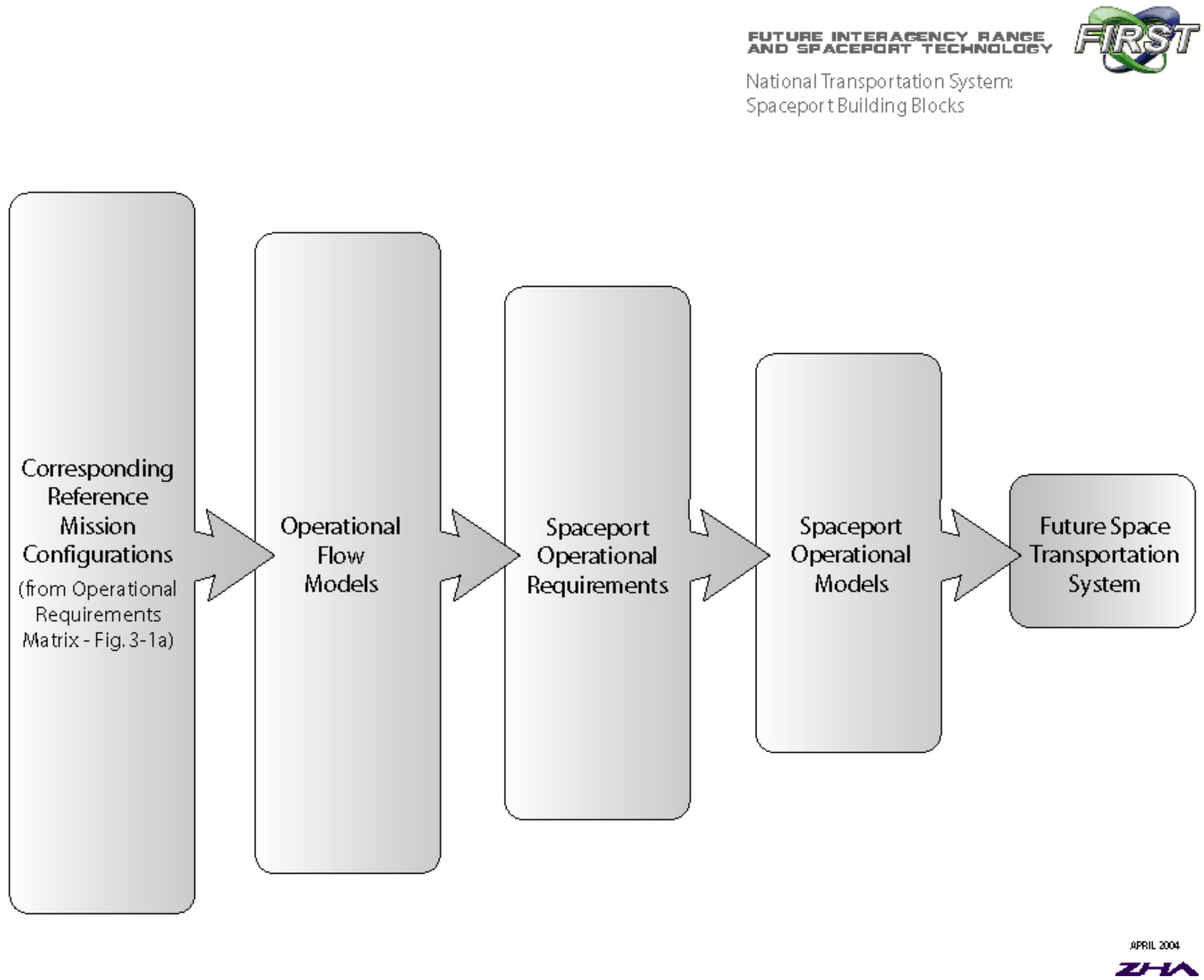
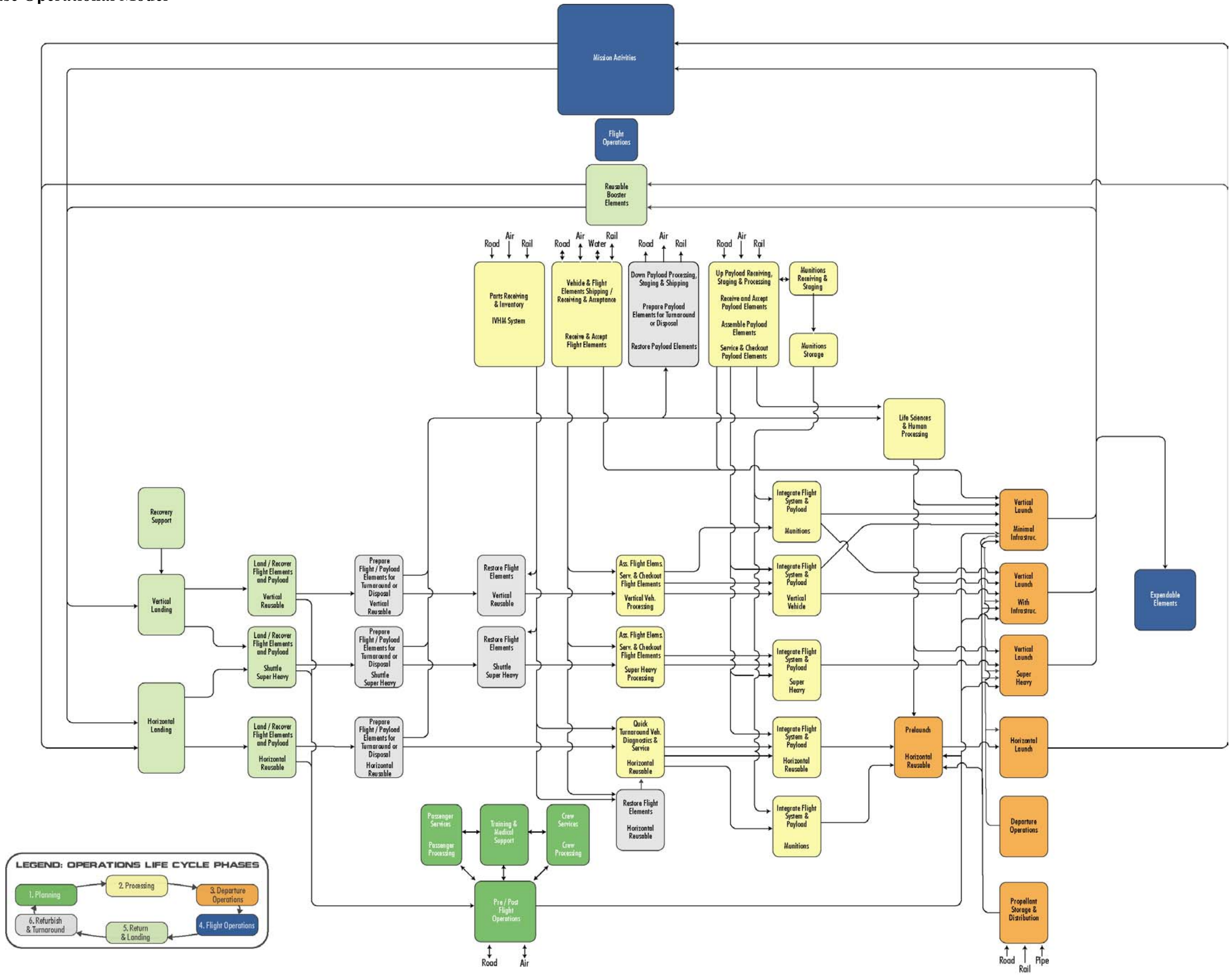


Figure ES-4 Spaceport Building Blocks

SPACEPORT BASE OPERATIONAL MODEL

Using the 15 Operational Flow Models and information generated by the evaluation of Operational Flow Models subfunction commonality, a flow model was developed (**Figure ES-5**) to graphically depict the interrelationships and component flow patterns between the subfunction elements of the 15 OFMs that describe an operational spaceport, which addresses mission requirements in a way that maximizes commonality of activities and the potential benefits of applied technology enhancements. A graphical depiction of the Base Operational Model with the 15 OFMs overlaid on the model was developed to visually present these commonalities.

Figure ES-5 Spaceport Base Operational Model



SPACEPORT COMPONENT MODELS (SCMS)

The Base Operational Model responds to and accommodates the mission requirements of all 15 OFMs. It is anticipated future market demand, driven by evolving vehicle technologies, emerging markets, and safety and security issues, will result in the spin-off of Spaceport Component Models, which respond to the specific operational requirements of one or more (but not all) OFMs to generate specialized Spaceport Component Models. Examples of potential spin-off SCMs include:

- National Security (Military) Spaceport
- Civil Space Exploration, Science & Research Spaceport
- Commercial Operations Spaceport
- Commercial Transportation Centers

Figure ES-6 summarizes the envisioned development of spaceport models by planning era in which a base operational model (BOM) accommodating numerous diverse mission requirements evolves over time with new technology-infused benefits. The BOM supports spin-off component models driven by market and mission demands with the most significant evolution of the FSTS coming in the third era, an era in which a global network of component models referred to as Commercial Transportation Centers (CTCs) develop ushering in an age of mass public space transportation.

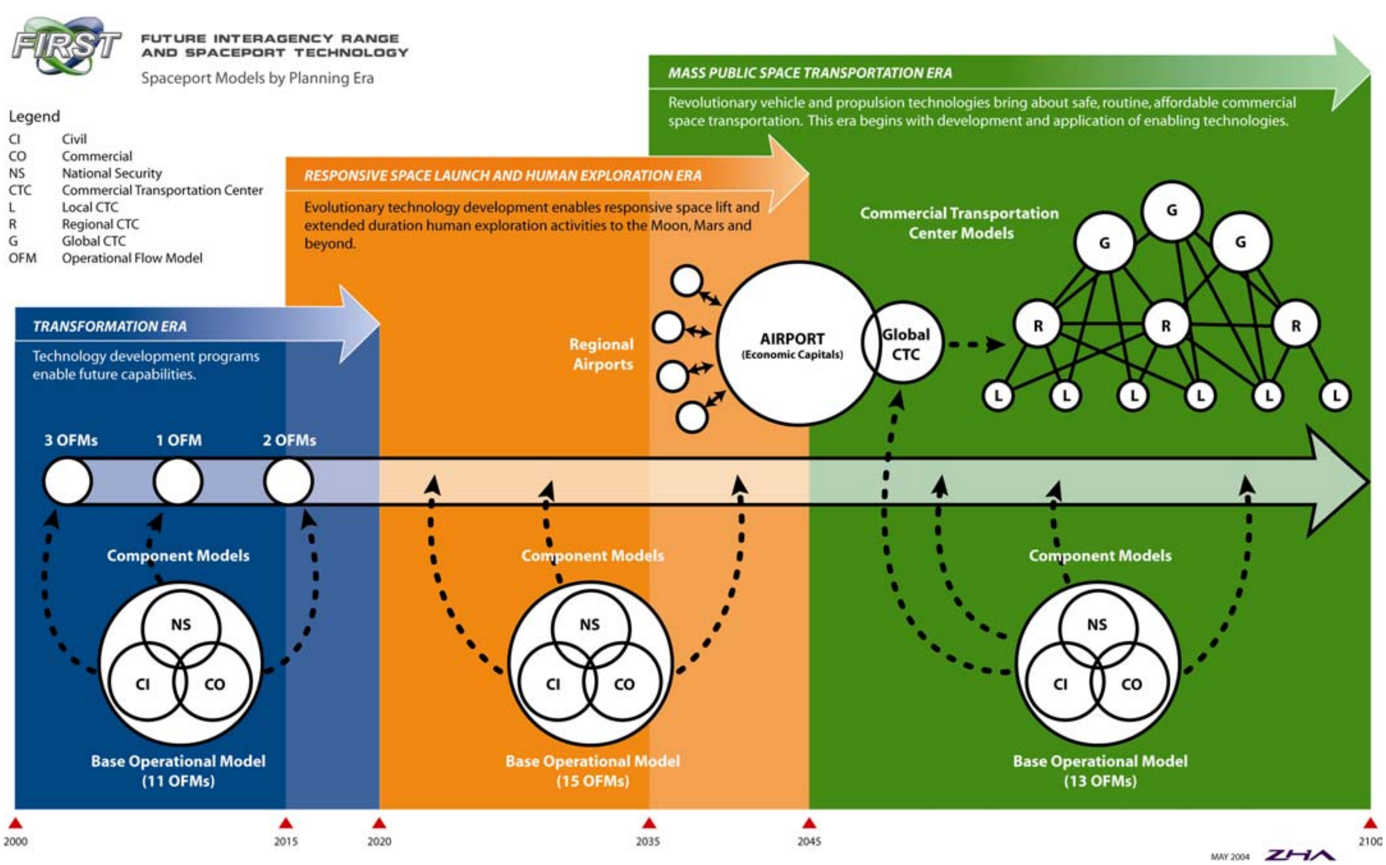


Figure ES-6 Spaceport Models By Planning Era

DAY IN THE LIFE SCENARIOS

To further illustrate how the base operational model may operate on a daily basis in the future, the CONOPS includes "Day in the Life" scenarios that describe how future spaceport operations and activities will be conducted using the envisioned future spaceport to support multiple types of operational space transportation missions and flight test activities. Six example missions were chosen from the three design reference mission categories to illustrate specific capabilities of future spaceport operations. The example missions include:

1. Routine commercial suborbital RLV flight
2. Routine scheduled NASA launch to support a crewed mission to the Moon
3. Routine scheduled NASA launch to support a crewed mission to Mars
4. Operationally Responsive Space (ORS) Prompt Global Strike (PGS) mission
5. Flight test of a new prototype DoD Hypersonic Cruise Vehicle (HCV)
6. Ballistic Missile Defense System (BMDS) flight test involving two targets and two interceptors

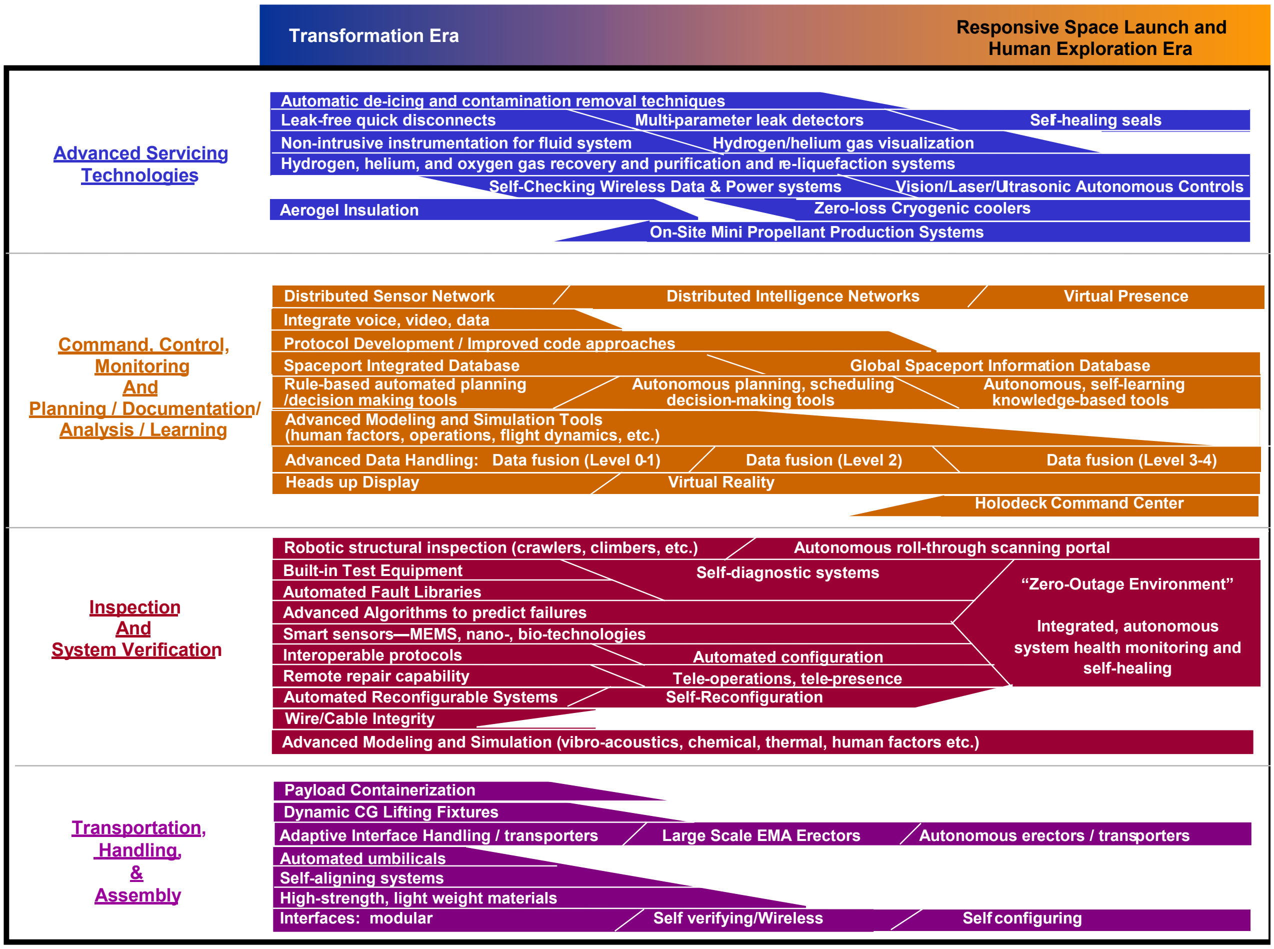
ENABLING TECHNOLOGIES

A variety of enabling capabilities will be necessary to develop the future spaceport architecture and operations described in this CONOPS. This CONOPS describes new ways of operating with capabilities that are likely to exist in the future. It describes a variety of technology focus areas and approaches that address the technical challenges that stand in the way of achieving the necessary capabilities for each of the spaceport functional areas.

The enabling technology roadmap depicted in **Figure ES-7** presents the recommended time-phased approach to pursuing these technology development activities in the first two planning timeframes, or eras. The five technology focus areas addressed in this section include:

- Advanced Servicing Technologies
- Command, Control, Monitoring
- Planning / Documentation / Analysis / Learning
- Inspection & System Verification
- Transportation, Handling, & Inspection

This CONOPS describes many opportunities and recommendations regarding technology focus areas that should be pursued to address each of these areas and enable the future spaceport capabilities envisioned in this CONOPS.



Source: ASTWG Baseline Report

Figure ES-7 Enabling Technology Roadmap

CONCLUSION

Pursuing opportunities for spaceport technology development will enable the realization of the future spaceport capabilities described in this CONOPS. Only by developing these capabilities will the future spaceports be able to support the anticipated future missions and achieve the vision for responsive, safe and efficient space transportation for civil, commercial, and national security missions, including eventual mass public space travel to rapidly move people and cargo between points on the globe and into space.

1.0 PURPOSE

In recognition of the national importance of routine and reliable access to space, the DoD Director of Operational Test and Evaluation (DOT&E), Air Force Space Command (AFSPC), NASA Kennedy Space Center (NASA KSC), and FAA's Associate Administrator for Commercial Space Transportation (FAA/AST) have partnered under the Future Interagency Range and Spaceport Technologies (FIRST) effort to jointly plan for cooperative development of technologies to enable the development of future spaceport and range systems and capabilities.

The purpose of this concept of operations (CONOPS) is to provide a common, national vision for this consortium with regard to the capabilities and operations of a future next-generation U.S. spaceport system concept. Specifically, this CONOPS describes how a future spaceport system supplemented by modernized range capability supports a variety of national security, civil, and commercial space launch operations and flight test activities when and where needed around the world.

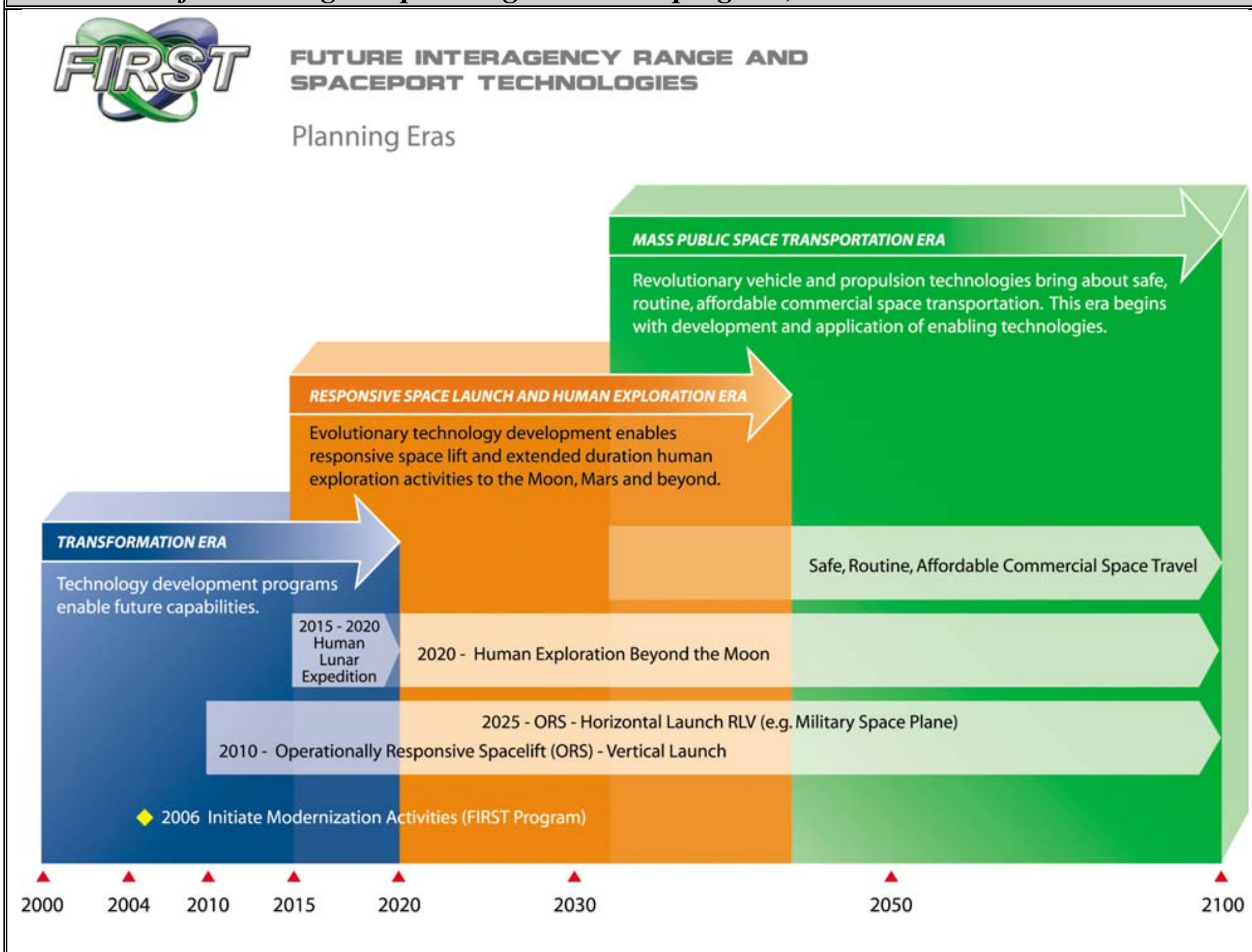
This CONOPS describes spaceport operations, elements and their desired characteristics in sufficient detail to enable decision-makers to identify areas for spaceport technology development. The intent is to enable concept approval prior to moving into technology gap assessments as well as business case, return on investment, and value proposition analyses.

2.0 TIME FRAMES

U.S. space transportation operations are expected to evolve from the current state of relying almost exclusively on vehicle-unique, ground-based assets through a series of spiral development steps to eventually effectuate routine and responsive spaceport operations for a variety of space access applications. These advances will be implemented across three conceptual timeframes depicted as "eras" in **Figure 2-1**. Spiral development processes focused on technology, operations, and performance advances will incrementally shift away from vehicle-unique infrastructure toward common use assets that provide greater flexibility and responsiveness as needed by emerging missions and vehicle architectures.

The first, or current, era is characterized by transformation. Transformation refers to fundamental change involving advanced technologies to enable new concepts of operation that are implemented and institutionalized through new policies, organizations, architectures, and economic and business models. These changes will initiate the fundamental shift away from vehicle-unique infrastructure, establishing the spiral development path for technology advances needed to support future missions.

In formulating and planning the FIRST program, three eras are addressed.



Source: FIRST Needs Assessment

Figure 2-1 FIRST Program Planning Eras

Such future missions characterize the second, or Responsive Space Launch and Human Exploration Era. This era is poised to begin within the next decade, with activities ramping up on a schedule that overlaps with the current era. Highlighting this overlap, these future missions are enabled by the Crew Exploration Vehicle (CEV) and operationally responsive spacelift (ORS) development efforts being pursued during the Transformation Era. Examples of the missions enabled by these capabilities include prompt global strike in support of military objectives as well as human space exploration missions to the moon, Mars, and beyond.

In the third era, the concept of Mass Public Space Transportation is envisioned to become a reality when the economics and technology of space travel align with the demands of a mass market. That is not to say there will not be commercial space passenger or parcel industry prior to the third era – this era signifies the period where those operations are as routine, affordable, and safe as today's air transportation system. In this era, it is anticipated that space transportation will become an integral part of the global mass public transportation system of the future. Such capabilities are recognized as being both visionary and revolutionary in terms of their ability to significantly improve the ability of future generations to rapidly move people and goods when and where needed anywhere in the world and into space.

3.0 ASSUMPTIONS

The Spaceport CONOPS is based on the following assumptions regarding future spaceport and range operations:

The development and evolution of horizontally launched vehicles is anticipated to result in a transition in launch-to-orbit mode from predominantly vertical in the Transformation Era to predominantly horizontal in the Mass Public Space Transportation Era. However, it is not anticipated horizontal launch vehicles will be appropriate for all launch demands currently met by vertical launch vehicles, or for super-heavy launch-to-orbit and exploration programs. It is assumed the spaceport base operating model will need to support three separate and distinct launch modes: vertical, vertical super-heavy, and horizontal. The proportion of facilities supporting the three launch modes will shift through the eras with the evolution of vehicle technology.

- The current shuttle program and potential future shuttle-derived super heavy lift launch vehicle configurations require the receipt, handling, processing and assembly of numerous large components in a manner unique to the program. <u>It is assumed, to the extent the shuttle program or other shuttle-derived programs of similar configuration continue in operation, the size and nature of processing, vehicle assembly and launch activities will necessitate facilities separate from other common use processing and launch facilities that might be developed for other in-line (stacked) vertical launch vehicle programs.</u>
- To capitalize on economies of shared use, it is anticipated most future spaceport payload shipping/receiving, handling, assembly and processing operations will be accomplished in common payload processing facilities. <u>It is assumed civil and commercial up payloads for all programs will be received and processed through one facility before being transported to other program locations for integration and down payloads will be similarly processed through the same common facility.</u> <u>It is also assumed military payloads (except for munitions) may be processed through common, shared-use payload processing facilities and security can be provided to appropriately isolate military payloads from the remainder of the facility, when necessary. It is also assumed military munitions and sensitive radioactive payloads will be received, processed, stored and integrated separately from other shared or common payload processing or integration facilities.</u>
- To capitalize on economies of shared use, it is assumed most future spaceport vehicle and vehicle component shipping/receiving, check-in and handling for both vertically and horizontally launched vehicles will be accomplished in common vehicle receiving and check-in facilities and after check-in, vehicles and components will be transferred to program areas for assembly and integration, or to common processing facilities for servicing, checkout, and preparation for flight.
- To capitalize on economies of shared use, it is assumed future spaceport parts inventory and control operations will be accomplished for all programs from one shared facility and that shipping/receiving, handling, automated storage and retrieval for most programs, excepting very large or specialized parts or elements will be accomplished from one common facility with ties to the IVHM (Integrated Vehicle Health Monitoring

system), which will manage inventory and parts distribution based on vehicle performance, maintenance and servicing requirements.

- Evolved horizontally operating reusable flight vehicles (MSP/OSP/HCV-type) will be horizontally processed for quick turnaround utilizing IVHM systems. Required service/routine turnaround maintenance will be accomplished and the vehicle ready for payload insertion and re-launch within a matter of hours of return from the previous flight. Vertically launched expendable and reusable vehicles will be received, assembled and processed in a more traditional manner similar to current procedures, requiring more time to process than reusable horizontal vehicles. It is assumed horizontal, quick turnaround vehicles will not be processed in the same facilities as vertically launched expendables and reusables, even if the vertical launch vehicles are processed horizontally.

- It is anticipated a variety of horizontally launched reusable flight vehicles will be developed for use in all operational sectors. To capitalize on operational economies of shared use, it is assumed many similar horizontally operating reusable flight vehicles will be processed within the same spaceport facilities. It is also assumed it will be acceptable to military operations for military vehicles to be processed through common maintenance/repair/service facilities, which would also simultaneously service similar non-military civil or commercial vehicles.

- The spaceport base operational model for each planning era assumes combined and shared utilization of spaceport assets by commercial, civil and military users as a means to capitalize on the financial benefits of shared use and to maximize the benefits of investment in new technologies. The need for economical and timely access to space is important to all prospective users but especially so for commercial users in meeting customer requirements. To this end it is assumed shared spaceport operations will be structured to facilitate timely access to space for all users without unnecessary delays or restrictions that would adversely affect their business plans and spaceport management procedures will be streamlined to facilitate responsive scheduling and launch.

- The planning era defined by mass public space transportation will be characterized by safe, routine, affordable hypersonic flights carrying passengers between earthly destinations. It is assumed the introduction of hypersonic transport vehicles for mass public transportation will be economically viable only if/when hypersonic vehicles can be assimilated into the evolved worldwide airport network (i.e. a network of Commercial Transportation Centers). Conversely, the development of a separate network of spaceports requiring connective infrastructure from remote locations to the evolved airport network (and related population centers) in order to address incompatible hypersonic vehicle operating characteristics would not be economically viable.

- Safety and reliability of currently operated expendable and partially reusable launch vehicles necessitate launch and operational flight paths that avoid populated areas. It is assumed future suborbital and orbital reusable launch vehicles (RLVs) associated with mass public space transportation operating in the third era will be so reliable as to be able to fly over populated areas without risks to public safety above the currently acceptable levels associated with commercial air traffic today.

- The introduction to the market of economical reusable vertical and horizontal launch vehicles and commercial transports and the resulting higher launch frequencies could create launch window and airspace conflicts (in timing and between vertical and horizontal operations) at spaceports, between spaceports and commercial air traffic operations and between spaceport ranges and the current commercial National Airspace System. It is assumed the future range will support routine space launch operations in ways that resemble today's management of the National Airspace System (NAS) in the era of mass public space transportation.

To address identified existing and future spaceport needs, an operational requirements matrix (database) was created with the launch configuration and other characteristics of all reference mission configurations (RMCs). Assumptions made regarding planned future missions are documented in the operational requirements matrix. A total of 74 individual reference mission configurations were identified and documented. The RMCs are organized into three categories: National Security, Civil and Commercial. See **Figure 3-1 a through c** (3 pages).

Spaceport Model Designations

NS – National Security

CI – Civil

CO – Commercial

CT – Commercial Transportation

FIRST Program - Spaceport CONOPS

Operational Requirements Matrix

12-Mar-04

Operational Flow Model	DRM Number	Capability	RMC ID Number	DRM Category	Spaceport Model NS	CI	CO	CT	Reference Mission Configuration (RMC)	Era	Established Operational Goal	Related Program	Classification	Crewed	Payload	Payload Capacity
National Security (NS)																
Testing & Evaluation																
B	3.2	Vertical launch to orbit - expendable	NS-TE1	TE	NS	CI	CO		Vertical launch of an ELV capable of delivering DOD payloads to LEO.	Near/Mid	On-going	Comm. & ISR satellite launch to orbit	Expendable	N	Various	Small
C	3.2	Vertical launch to target - expendable	NS-TE2	TE	NS				Vertical launch of an ELV with CAV or similar payload / CAV is released and flies controlled glide trajectory to target.	Near/Mid	USAF 2010	SLV launch program. DARPA FALCON near program for CAV and Enhanced CAV. NOTU Trident testing program.	Expendable	N	CAV / Weapons	Small
C	3.3	Vertical launch to in-flight target intercept - expendable	NS-TE3	TE	NS				On-demand vertical launch of multiple vehicles from multiple locations on ballistic trajectory to intercept target in flight.	Near/Mid		Missle defense system.	Expendable	N	Weapons	Small
L	3.1	Horizontal launch - horizontal recovery	NS-TE4	TE	NS	CI	CO		HCV with RBCC engine(s) launches horizontally, climbs to sub-orbital altitude for flight testing and maneuver. Returns to horizontal landing facility at same location.	Mid/Far	USAF 2025	Hypersonic Cruise Vehicle (HCV) DARPA FALCON far-term program based on next-gen propulsion systems development.	RSV	N	CAV /Weapons / Satellite	Medium
J	3.1	Air-launch - horizontal recovery	NS-TE5	TE	NS				MSP or related test-bed vehicle air-launched from aircraft, controlled glide test to horizontal landing facility at same location.	Near	On-going	Drop test and Pegasus test bed programs for MSP vehicle development.	RSV	N	MSP test bed platforms	Small
F	3.4	Vertical launch - horizontal recovery	NS-TE6	TE	NS				MSP or related test-bed vehicle launched vertically to orbit on an ELV / controlled glide or powered flight testing / conducts reentry and controlled descent to horizontal landing facility at same location.	Near/Mid		Conventional ELV launch program. MSP vehicle development.	Expendable/RSV	N	CAV /Weapons / Satellite	Medium
K	3.1	Horizontal launch - horizontal recovery	NS-TE7	TE	NS				High altitude MIPCC-powered jet aircraft first stage launches horizontally and climbs to 100,000 feet where disposable conventional rocket second stage propels small payload to LEO / first stage returns to horizontal landing facility at same location.	Near/Mid	On-going DARPA - Flight test 2006	DARPA RASCAL (Responsive Access, Small Cargo, and Affordable Launch) Program	Reusable / Expendable	N	Small Payloads	Small Up to 220 lbs.
K	3.1	Horizontal launch - horizontal recovery	NS-TE8	TE	NS				MSP launched horizontally under own rocket/RBCC power to near orbit or LEO / conducts reentry and executes controlled descent to horizontal landing facility at same location.	Mid/Far		Autonomous vehicle with next-gen propulsion systems.	RSV	N	CAV /Weapons / Satellite	Medium
Weapons Delivery																
C	2.5	Vertical launch to target - expendable	NS-MD1	RE	NS				On-demand vertical launch of an ELV with DOD payload on ballistic trajectory to target.	Near	On-going	Current programs	Expendable	N	Weapons	Small
C	2.1	Vertical launch to target - expendable	NS-MD2	RE	NS				On-demand vertical launch of an ELV on ballistic trajectory / releases CAV which continues on ballistic trajectory executing controlled glide to target.	Near/Mid	USAF 2010	Small Launch Vehicle (SLV) and CAV near-term operational programs. (DARPA FALCON)	ELV/Expendable	N	CAV / Weapons	Small
C	2.6	Vertical launch to in-flight target intercept - expendable	NS-MD3	RE	NS				On-demand vertical launch of multiple vehicles on ballistic trajectory to intercept target in flight.	Near/Mid		Missle defense system.	Expendable	N	Weapons	Small
L	2.1	Horizontal launch - horizontal recovery.	NS-MD4	RE	NS				On-demand of MSP or HCV with single/multiple CAV payload, climbs to high sub-orbital or orbital trajectory where CAVs are dispensed at high velocity for continued ballistic flight and controlled glide to target area(s). Vehicle returns to horizontal landing facility at same location.	Mid/Far	USAF 2025	Hypersonic Cruise Vehicle operational program. (DARPA FALCON) Operationally Responsive Spacelift-Prompt Global Strike	RSV/Expendable	N	CAV / Weapons	Medium
Communications/Control																
B	2.2	Vertical launch to orbit - expendable	NS-CO1	RO	NS				Vertical launch of DOD communications satellite on an expendable ELV booster to LEO.	Near/Mid	On-going	Conventional ELV launch program. Communications and airspace/range control systems.	Expendable	N	Satellite/Other	Small
K	2.2	Horizontal launch to orbit - horizontal recovery	NS-CO2	RO	NS				Horizontal launch of DOD satellite in MSP payload bay to near orbit or LEO / satellite ejected from payload bay for insertion to LEO. MSP conducts reentry and returns to horizontal landing facility at same location.	Mid/Far	Est. 2030	Operational MSP or HCV program for delivery to orbit. Communications and airspace/range control systems.	RSV	N	Satellite/Other	Meduim
Intelligence, Surveillance, Reconnaissance																
B	2.2	Vertical launch to orbit - expendable	NS-ISR1	RE	NS				On-demand launch of DOD microsatellite vertically on an ELV to LEO / microsatellite booster stage facilitates rendezvous with un-identified orbiting spacecraft for identification purposes. All elements expendable.	Near/Mid		Small conventional ELV program. Operationally Responsive Spacelift (ORS) Space Control Microsatellite program.	ELV	N	Microsatellite	Small
K	2.2	Horizontal launch to orbit- horizontal recovery	NS-ISR2	RE	NS				On-demand launch of DOD microsatellite horizontally in MSP payload bay to near orbit or LEO / satellite ejected from payload bay and booster stage facilitates rendezvous with un-identified orbiting spacecraft for identification purposes. MSP conducts reentry and returns to horizontal landing facility at same location.	Mid/Far	Est. 2030	Evolved MSP program. Operationally Responsive Spacelift (ORS) Space Control Microsatellite program.	RSV	N	Microsatellite	Small
F	2.2	Vertical launch to orbit - reusable - horizontal recovery	NS-ISR3	RE	NS				On-demand launch of MSP vertically on ELV to polar LEO. ISR payload accomplishes mission objectives. MSP conducts reentry and returns to horizontal landing facility at same location.	Near/Mid		Conventional ELV and operational first gen. MSP program. Operationally Responsive Spacelift (ORS) ISR program.	RSV	N	ISR Instrumentation	Small
K	2.2	Horizontal launch - horizontal recovery	NS-ISR4	RE	NS				On-demand horizontal MSP launch to polar LEO. ISR payload accomplishes mission objectives. MSP conducts reentry and returns to horizontal landing facility at same location.	Mid/Far	Est. 2030	Operational evolved autonomous Military Spaceplane (MSP) program. Operationally Responsive Spacelift (ORS) ISR program.	RSV	N	ISR Instrumentation	Small
Civil Space Exploration, Science & Research (CI)																
Testing & Evaluation																
	3.5	Static Testing	CI-TE1	TE		CI	CO		Static testing and evaluation of vehicle propulsion systems and related components.	Near/Mid/Far	On-going	Evolving propulsion systems development programs. Vehicle manufacturing and maintenance facilities.	ELV/RSV	N	None	N/A
B	3.2	Vertical launch to orbit - expendable or partially reusable	CI-TE2	TE		CI	CO		Vertical launch of small to increasingly heavier lift capacity ELV boosters and evolving propulsion technologies capable of delivering payloads to low Earth orbit and/or deep space destinations.	Near/Mid/Far	On-going	Development of new launch vehicles of increasing lift capacities by civil or commercial entities using new technologies and systems to achieve economical	ELV / RLV	N	Vehicles / Cargo / Other Payloads	Small to Super-Heavy
B	3.2	Vertical launch to orbit - expendable or partially reusable	CI-TE3	TE		CI			Vertical launch of an expendable or partially reusable super-heavy-lift launch vehicle to place large mass objects into LEO.	Near	NASA 2008+	Super Heavy Lift Vehicles for Moon/Mars Program and other evolving vertical lift technologies.	ELV	N	Vehicles / Cargo / Other Payloads	Super Heavy
E	3.1	Vertical launch to orbit - expendable/reusable - vertical recovery	CI-TE4	TE		CI			Vertical launch of an ELV to place unmanned/manned capsule in orbit for vertical water recovery.	Near/Mid	NASA 2014+	Development of CEV capsule and related Moon/Mars mission components	ELV/RSV	N	Space Vehicle	Heavy to Super-Heavy
E	3.1	Vertical launch to orbit - expendable/reusable - vertical recovery	CI-TE5	TE		CI			Vertical launch of an ELV to place unmanned/manned capsule in orbit for vertical on-land recovery.	Near/Mid		Development of CEV capsule and related Moon/Mars mission components	ELV/RSV	N	Space Vehicle	Heavy to Super-Heavy
I	3.4	Vertical launch to orbit-vertical recovery - reusable	CI-TE6	TE		CI			Vertical launch of an unmanned/manned SSTO vehicle to sub-orbital/orbital destination for testing / conducts reentry and powered vertical return to same location.	Near/Mid/Far		Vertical launch - vertical powered landing vehicle.	RSV	Y/N	Crew / payload	Heavy to Super-Heavy
G	3.2	Vertical launch to orbit - expendable/reusable - horizontal recovery	CI-TE7	TE		CI			Vertical launch of an ELV to place a manned vehicle in orbit with reentry and return to horizontal landing facility at same location.	Near/Mid		CEV Development Program	ELV/RSV	Y	Crew / payload	Heavy to Super-Heavy
F	3.4	Vertical launch to orbit - expendable/reusable - horizontal recovery	CI-TE8	TE		CI			Vertical launch unmanned/manned vehicle to sub-orbital/orbital testing- return to horizontal landing facility.	Mid/Far		Civil equivalent of next generation vertical launch MSP development.	RSV	Y/N	Crew / payload	Heavy to Super-Heavy
K	3.4	Horizontal launch to orbit - reusable - horizontal recovery	CI-TE9	TE		CI			Horizontal launch unmanned/manned vehicle to sub-orbital/orbital destination with re-entry and return to horizontal landing facility at same location.	Mid/Far		Civil equivalent of next generation MSP/HCV development.	RSV	Y/N	Crew / payload	Heavy to Super-Heavy
		Horizontal Launch Assist Tech. Dev.	CI-TE10	TE		CI			Develop ground-based launch assist system for horizontal launch vehicles.	Near/Mid/Far		MagLifter & StarTram Programs	RLV/RSV	N	RSV	N/A
		Vertical Lift to Orbit	CI-TE11	TE		CI			Development of system or technologies to raise and lower payloads to/from a fixed point in orbit.	Mid/Far		Space Elevator	RLV	Y/N	Vehicles / Cargo / Payload / People	Light to Super Heavy

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Spaceport Model Designations

NS – National Security

CI – Civil

CO – Commercial

CT – Commercial Transportation

FIRST Program - Spaceport CONOPS

Operational Requirements Matrix

12-Mar-04

Operational Flow Model	DRM Number		Capability	RMC ID Number	DRM Category	Spaceport Model NS	CI	CO	CT	Reference Mission Configuration (RMC)	Era	Established Operational Goal	Related Program	Classification	Crewed	Payload	Payload Capacity
		Payload to Orbit															
A	1.6		Vertical launch - Sounding Rocket	CI-PO1	RO		CI	CO		Vertical launch of rocket to conduct tests/experiments and gather data.	Near/Mid	On-going		ELV	N	Instrumentation	Small
B	1.1		Vertical launch to orbit - expendable	CI-PO2	RO		CI	CO		Vertical launch of satellite to low to medium Earth orbit on an ELV from various potential locations depending on desired orbit.	Near/Mid/Far	On-going	Civil payload to orbit	ELV	N	Satellite	Light to Medium
J	1.7		Air launch to orbit - reusable/expendable - horizontal recovery	CI-PO3	RO		CI	CO		Air launch of small satellite to low to medium Earth orbit on an expendable booster carried to launch location by conventional aircraft first stage which returns to horizontal recovery facility.	Near/Mid	On-going	Civil small payload to orbit-Pegasus	RLV	N	Satellite	Small
K	1.7		Horizontal launch to orbit - reusable - horizontal recovery	CI-PO4	RO		CI	CO		Horizontal launch of satellite in RLV payload bay to low to mid Earth orbit/ satellite ejected from payload bay for insertion to orbit. Vehicle conducts reentry and returns to horizontal landing facility at same location.	Mid/Far	Est. 2035	Civil payload to orbit on HCV-type vehicle.	RSV	N	Satellite	Medium
			Vertical Lift to Orbit	CI-PO5	RO		CI	CO		Operation of system to raise and lower payloads to/from a fixed point in orbit.	Mid/Far		Space elevator operations.	RLV	Y/N	Vehicles / Cargo / Payload / People	Light to Super Heavy
	1.0	Exploration															
B	1.3		Vertical launch to Lunar Exploration, unmanned - expendable	CI-EX1	RO		CI			Vertical launch of satellite on ELV to the Moon / insertion of satellite into lunar orbit for digital mapping or related information gathering purposes-all expendable.	Near	Est. 2008	Lunar mapping	ELV	N	Satellite	Intermediate
B	1.3		Vertical launch to Lunar Exploration, unmanned - expendable	CI-EX2	RO		CI			Vertical launch of robotic (lander/rover) on ELV to LEO / trans-Lunar injection to the Moon / insertion into lunar orbit / descent to surface / deployment of rover-all expendable.	Near	Est. 2009	Lunar rover(s)	ELV	N	Robot/Rover	Intermediate
G	1.3		Vertical launch to Lunar Exploration, crewed - partially reusable	CI-EX3	RO		CI			Vertical launch of CEV and Lunar mission components on ELV to LEO / trans-Lunar injection to the Moon and insertion to Lunar orbit / lander vehicle decent to surface / surface operations / return vehicle ascent to CEV module / CEV module trans-Earth injection and LEO insertion / reentry and vertical descent to water landing.	Near/Mid	Est. 2015	Manned Lunar Landing Mission	Partially Reusable System	Y	Crew / Cargo	Heavy to Super-Heavy
B	1.4		Vertical launch to Planetary Exploration, unmanned - expendable	CI-EX4	RO		CI			Vertical launch of satellite on ELV to LEO / trans-planetary injection to Mars or other deep space destination / insertion of satellite to planetary orbit for digital mapping or related information gathering purposes-all expendable.	Near		Mars mapping	ELV	Y	Satellite	Intermediate
B	1.3		Vertical launch to Planetary Exploration, unmanned - expendable	CI-EX5	RO		CI			Vertical launch of robotic (lander/rover) on ELV to LEO / trans-planetary injection to planet or other deep space destination / insertion to orbi t/ descent to surface / deployment of rover with option for sample return with inclusion of ascent and return vehicles / all expendable except ascent-return components of sample return mission with vehicle returning to Earth orbit and descending to recovery on land.	Near/Mid	On-going	Mars rovers/robots	Partially Reusable System	N	Robot/Rover	Intermediate
H	1.4		Vertical launch to Planetary Exploration, crewed - partially reusable	CI-EX6	RO		CI			Multiple vertical launches of crew habitat and mission modules to LEO via new super heavy lift launch vehicle / transport stage performs trans-Mars injection and insertion to Mars orbit / habitat, ascent and support modules descent to surface via integral descent capability, return module remains in Mars orbit / subsequent Earth launch of crew and second habitat module transports crew to Mars surface / surface activities accomplished / ascender vehicle and crew returns to Mars orbit & rendezvous with orbiting return vehicle for trans-Earth injection and insertion to LEO / CEV reenters Earth atmosphere and returns to horizontal recovery facility.	Mid/Far	Est. 2020+	Manned Mars Mission	Partially Reusable System	Y/N	Vehicles / Cargo / Payload / People	Multiple Heavy to Super-Heavy
B	1.3		Vertical launch to Deep Space Exploration, unmanned - expendable	CI-EX7	RO		CI			Vertical launch of an ELV to place probe/robotic payloads in orbit or deep space.	Near/Mid/Far		Deep Space Probe/Rover Missions	ELV	N	Probe/Rover	Heavy
D	1.4		Vertical launch to Lunar Base(Planetary Base Similar), unmanned - partially reusable	CI-EX8	RO		CI			Multiple vertical launches of base components and cargo to LEO via partially reusable heavy-lift vertical launch vehicle / transfer of components and cargo to Lunar orbit via trans-Lunar injection stage with insertion to Lunar orbit / component and cargo descent to surface via integral descent capability.	Mid/Far		Establish Lunar/Planetary Base. Assumes crew, habitat and return modules already established on surface, per CI-EX6.	Partially Reusable System	Y/N	Cargo / Components	Multiple Heavy to Super-Heavy
B	1.1		Vertical launch from Lunar base, unmanned - expendable	CI-EX9	RO		CI			Vertical launch from lunar base to planetary destination.	Mid/Far			ELV/RLV	Y/N		
G	2.3		Vertical launch - Horizontal recovery - Rescue mission, crewed - partially reusable	CI-EX10	RE		CI			On-demand vertical launch of Space Shuttle or CEV to ISS for crew rescue mission / reentry and controlled decent to horizontal landing facility at same location.	Near	To 2012	ISS/Shuttle missions or Soyuz Program..	Partially RSV	Y	Crew / Supplies	Super-Heavy
O	2.3		Horizontal launch - horizontal recovery - Rescue mission, crewed - reusable	CI-EX11	RE		CI			On-demand horizontal launch of HCV-type transport vehicle to any LEO destination for rendezvous with orbiting space station or other spacecraft for crew rescue mission. After completion of mission, vehicle reenters atmosphere and descends to horizontal landing	Mid/Far	Est. 2035	HCV-type SSTO vehicle used as rescue vehicle.	RSV	Y/N	Crew / Supplies / Materials	Intermediate
		Science															
B	1.1		Vertical launch to orbit - expendable	CI-S1	RO		CI	CO		Vertical launch of satellite to low to medium Earth orbit on an ELV from various potential locations based on desired orbit.	Near/Mid	On-going	Micro Satellite/Platform - ELV - Earth science missions.	ELV	N	Satellite	Small
J	1.7		Air launch to orbit - reusable/expendable - horizontal recovery	CI-S2	RO		CI	CO		Air launch of small satellite to low to medium Earth orbit on an expendable booster carried to launch location by conventional aircraft first stage, which returns to horizontal landing facility at same location.	Near/Mid	On-going	Pegasus-like Earth science missions.	RLV/ELV	N	Satellite	Small
K	1.7		Horizontal launch to orbit - reusable - horizontal recovery	CI-S3	RO		CI	CO		Horizontal launch of satellite in RSV payload bay to low to mid Earth orbit/ satellite ejected from payload bay for insertion to orbit. Vehicle conducts reentry and returns to horizontal landing facility at same location.	Mid/Far	Est. 2035	Civil equivalent of next gen. MSP/HCV development for Earth science missions.	RSV	N	Satellite	Medium
B	1.1		Vertical launch to orbit - expendable	CI-S4	RO		CI	CO		Vertical launch of satellite to low or medium Earth orbit or to deep space on an ELV from various potential locations based on desired orbit or destination.	Near/Mid/Far	On-going	Current and evolving launch vehicle programs to place payloads in orbit.	ELV	N	Satellite	Small to Medium
D	1.4		Vertical launch to deep space - expendable	CI-S5	RO		CI			Vertical launch of an unmanned probe/rover to deep space on a super heavy lift ELV.	Near/Mid	Est. 2014-2015	Jupiter Icy Moons Rover/Project Prometheus nuclear propulsion systems development/super heavy lift booster development.	ELV	N	Vehicle/Probe	Super-Heavy
D	1.4		Vertical launch to orbit - partially reusable	CI-S6	RO		CI			Scheduled vertical launch of super heavy lift partially reusable launch vehicle carrying space station (or other large facility/vehicle) components to orbit for on-orbit assembly.	Near/Mid	To 2017	STS-Cargo or other super heavy lift vehicle to facilitate construction/assembly of large objects on-orbit.	Partially RSV	N	Components / Cargo	Super-Heavy
G	1.2		Vertical launch to orbit, crewed - partially reusable - horizontal recovery	CI-S7	RO		CI			Vertical launch of Space Shuttle to ISS with components for assembly on-orbit / reentry and controlled decent to horizontal landing facility at same location.	Near	To 2012	ISS construction/Shuttle missions.	Partially RSV	Y	Components / Cargo / crew	Super-Heavy
G	1.2		Vertical launch to orbit, crewed - partially reusable - horizontal recovery	CI-S8	RO		CI			Vertical launch of Space Shuttle to ISS for re-supply and crew transfer mission / reentry and controlled decent to horizontal landing facility at same location.	Near	To 2012	ISS/Shuttle missions or Soyuz Program..	Partially RSV	Y	Crew / Supplies	Super-Heavy
O	1.7		Horizontal launch to orbit, crewed or uncrewed - reusable - horizontal recovery	CI-S9	RO		CI	CO		Scheduled horizontal launch of HCV-type transport vehicle to any LEO destination for rendezvous with orbiting space station for supply and personnel transfer to and from Earth surface. After completion of mission, vehicle reenters atmosphere and descends to horizontal landing facility at manufacturers base of operations.	Mid/Far	Est. 2035	HCV-type SSTO vehicle used as transfer vehicle or operations lab for on-orbit maunfacturing/research operations.	RSV	Y/N	Crew / Supplies / Materials	Intermediate
Commercial (CO)																	
		Testing & Evaluation															
B	3.2		Vertical launch to orbit - expendable	CO-TE1	TE		CI	CO		Vertical launch of small to increasingly heavier lift capacity ELV boosters and evolving propulsion technologies capable of delivering payloads to low Earth orbit and/or deep space destinations.	Near/Mid/Far	On-going	Programs begin with small lift capability and expand to larger mass-class vehicles. Focus on low cost reusable vehicles and lowest applicable technologies.	ELV	N	Satellites	Small to Heavy

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Spaceport Model Designations

NS – National Security

CI – Civil

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CT – Commercial Transportation

FIRST Program - Spaceport CONOPS

Operational Requirements Matrix

12-Mar-04

Operational Flow Model	DRM Number		Capability	RMC ID Number	DRM Category	Spaceport Model NS	CI	CO	CT	Reference Mission Configuration (RMC)	Era	Established Operational Goal	Related Program	Classification	Crewed	Payload	Payload Capacity
I	3.1		Vertical launch sub-orbital, crewed - reusable - vertical recovery	CO-TE2	TE		CI	CO		Vertical launch of manned RSV / capsule to sub-orbital trajectory with descent to vertical recovery on water.	Near	On-going	X-Prize or similar developmental effort.	RSV	Y	Passengers/Crew	Small
I	3.1		Vertical launch sub-orbital, crewed - reusable - vertical recovery	CO-TE3	TE		CI	CO		Vertical launch of manned RSV / capsule to sub-orbital trajectory with descent for vertical land recovery.	Near	On-going	X-Prize or similar developmental effort.	RSV	N	Passengers/Crew	Small
I	3.1		Vertical launch sub-orbital, crewed - reusable - horizontal recovery	CO-TE4	TE		CI	CO		Vertical launch of manned RSV to sub-orbital trajectory with descent to horizontal recovery on land.	Near	On-going	X-Prize or similar developmental effort.	RSV	Y	Passengers/Crew	Small
N	3.1		Horizontal launch sub-orbital, crewed - reusable - horizontal recovery	CO-TE5	TE		CI	CO		Horizontal launch of a manned RSV climbs to sub-orbital trajectory and descends for horizontal recovery on land.	Near	On-going	X-Prize or similar developmental effort.	RSV	Y	Passengers/Crew	Small
M	3.1		Horizontal launch sub-orbital, crewed - reusable - horizontal recovery	CO-TE6	TE		CI	CO		Horizontal launch of manned vehicle to sub-orbital/orbital destination with re-entry and return to horizontal landing facility at same location.	Mid/Far	Est. 2035	Commercial equivalent of next generation HCV development.	RSV	Y	Passengers/Crew	Heavy to Super-Heavy
K	3.4		Horizontal launch to orbit - reusable - horizontal recovery	CO-TE7	TE		CI	CO		Horizontal launch of unmanned vehicle to sub-orbital/orbital destination with re-entry and return to horizontal landing facility at same location.	Mid/Far	Est. 2035	Commercial equivalent of next generation MSP development.	RSV	N	Cargo	Medium
		Space Tourism															
I	1.5		Vertical launch sub-orbital, crewed - reusable - vertical recovery	CO-ST1	RO			CO		Vertical launch of passenger-carrying vehicle to near orbit altitude followed by controlled vertical decent and subsequent parachute landing at designated landing site on land or water.	Near/Mid	2005+	Evolutionary X-Prize or similar commercial venture.	RSV	Y	Passengers/Crew	Small
E	1.1		Vertical launch to orbit, crewed - expendable - vertical recovery	CO-ST2	RO		CI	CO		Vertical launch of passenger-carrying vehicle to LEO and rendezvous with orbiting space station/destination followed by reentry and vertical decent and subsequent parachute landing at designated landing site on land or water.	Near/Mid	On-going	Soyuz mission to ISS. Others to follow?		Y	Passengers/Crew Cargo	Medium
I	1.5		Vertical launch sub-orbital, crewed - reusable - horizontal recovery	CO-ST3	RO			CO		Vertical launch of passenger-carrying vehicle to near orbit altitude followed by initial controlled vertical decent and subsequent controlled horizontal parafoil glide to designated landing site on land.	Near/Mid	2005+	Evolutionary X-Prize or similar commercial venture.	RSV	Y	Passengers/Crew	Small
N	1.5		Horizontal launch sub-orbital, crewed - reusable - horizontal recovery	CO-ST4	RO			CO		Horizontal launch of passenger-carrying spacecraft or carrier aircraft for air-launch and climb to near orbit altitude followed by controlled glide/powered decent and return to horizontal landing facility at same location.	Near/Mid	2004+	Evolutionary X-Prize or similar commercial venture.	RSV	Y	Passengers/Crew	Small
O	1.7		Horizontal launch to orbit, crewed - reusable - horizontal recovery	CO-ST5	RO			CO		Horizontal launch of passenger-carrying spacecraft and climb to LEO and rendezvous with orbiting space station/destination followed by controlled glide/powered decent and return to horizontal landing facility at same location.	Mid/Far	Est. 2040	Commercial version of evolved HCV technology adapted for space transportation.		Y	Passengers/Crew Cargo	Heavy to Super-Heavy
	CT	**Mass Public Space Transportation**															
M	1.5		Horizontal launch sub-orbital, crewed - reusable - horizontal recovery	CO-PT1	RO				CT	Operation of an evolved HCV-type passenger-carrying commercial vehicle, launches horizontally from a commercial spaceport or conventional airport runway and climbs to sub-orbital altitude for trans/intercontinental trips before descending for horizontal landing at similar commercial facility.	Mid/Far	Est. 2040	Commercial version of evolved HCV technology anticipated for intercontinental public transportation.	RSV	Y	Passengers/Crew Cargo	Heavy to Super-Heavy
		Payload to Orbit															
B	1.1		Vertical launch to orbit - expendable	CO-PO1	RO		CI	CO		Vertical launch of satellite to low or medium Earth orbit on an ELV from various potential locations depending on desired orbit.	Near/Mid/Far	On-going	Commercial payload to orbit	ELV	N	Satellite	Small to Medium
J	1.7		Air launch to orbit - reusable/expendable - horizontal recovery	CO-PO2	RO		CI	CO		Vertical launch of small satellite to low or medium Earth orbit on an air-launched expendable booster carried to launch location by conventional aircraft first stage which returns to horizontal recovery facility.	Near/Mid	On-going	Commercial small payload to orbit-Pegasus	RLV	N	Satellite	Small
K	1.7		Horizontal launch to orbit - reusable - horizontal recovery	CO-PO3	RO		CI	CO		Horizontal launch of a satellite in an RLV payload bay to low or mid Earth orbit / satellite ejected from payload bay for insertion to orbit / vehicle conducts reentry and returns to horizontal landing facility at same location.	Mid/Far	Est. 2035	Commercial payload to orbit on HCV-type vehicle.	RSV	N	Satellite	Medium
			Vertical Lift to Orbit	CO-PO4	RO		CI	CO		Operation of system to raise and lower payloads to/from a fixed point in orbit.	Mid/Far		Space elevator operations.	RLV	Y/N	Passengers/Crew Cargo/Vehicles	Light to Super Heavy
		Operations on Orbit															
D	1.4		Vertical launch to orbit - partially reusable	CO-OO1	RO		CI	CO		Vertical launch of laboratory module or space laboratory components in one or more heavy/super heavy-lift ELV missions to LEO.	Mid/Far		On-orbit manufacturing/research operations in commercial space laboratory or orbiting laboratory module.	ELV	N	Equipment/Cargo	Heavy to Super-Heavy
F	1.1		Vertical launch to orbit - expendable/reusable - horizontal recovery	CO-OO2	RO		CI	CO		Vertical launch of robotic service vehicle on ELV to various LEO destinations for rendezvous with orbiting satellite for maintenance, fueling or capture and return operations. After completion of mission, vehicle reenters atmosphere and descends to horizontal recovery facility at same location.	Near/Mid		MSP-type vehicle with robotic capabilities or payload for on-orbit commercial service and refueling operations.	RSV	N	Service Equipment Satellite	Small to Medium
K	1.7		Horizontal launch to orbit - reusable - horizontal recovery	CO-OO3	RO		CI	CO		Horizontal launch of HCV-type service vehicle to any LEO destination for rendezvous with orbiting satellite for maintenance, fueling or capture and return operations. After completion of mission, vehicle reenters atmosphere and descends to horizontal recovery facility at same location.	Mid/Far		HCV-type SSTO vehicle with robotic capabilities or payload related to on-orbit service and maintenance operations.	RSV	Y	Service Equipment Satellite	Small to Medium
O	1.7		Horizontal launch to orbit, crewed/uncrewed - reusable - horizontal recovery	CO-OO4	RO		CI	CO		Horizontal launch of HCV-type transport vehicle to any LEO destination for rendezvous with orbiting space laboratory for personnel, materials and product transfer to and from earth surface. After completion of mission, vehicle reenters atmosphere and descends to horizontal landing facility at manufacturers base of	Mid/Far		HCV-type SSTO vehicle used as transfer vehicle or operations lab for on-orbit maunfacturing/research operations.	RSV	Y	Passengers/Crew Cargo/Product	Intermediate
		Operations Beyond Orbit															
B	1.1		Vertical launch to deep space - expendable	CO-OBO1	RO			CO		Vertical launch of MSTO ELV for delivery of various commercial payloads to solar or deep space destinations.	Near/Mid	On-going	Space burial, waste disposal	ELV	N	Cargo	Small
B	1.3		Vertical launch to deep space - expendable	CO-OBO2	RO		CI	CO		Vertical launch of robotic (lander/rover) on ELV trajectory to planetary or other deep space destination / insertion into orbit / descent to surface / deployment of rover/excavator for material collection / return with ascent and return vehicle capability / all expendable except ascent-return components with vehicle returning to Earth orbit and descending to horizontal recovery on land at space mining facility.	Mid/Far	Est. 2040	Space mining operations focusing on low quantity/high value materials as may be discovered through space exploration operations.	ELV/RSV	N	Cargo	Intermediate
O	1.7		Horizontal launch to orbit, crewed - reusable - horizontal recovery	CO-OBO3	RO			CO		Horizontal launch of evolved HCV-type payload and/or passenger-carrying commercial vehicle to near orbit or LEO with capacity to jettison/launch booster-propelled payload containers to solar or deep space destinations / followed by controlled decent and return to horizontal landing facility at same location.	Mid/Far	Est. 2040	Space burial, waste disposal	RSV	Y	Passengers/Crew Cargo	Heavy to Super-Heavy

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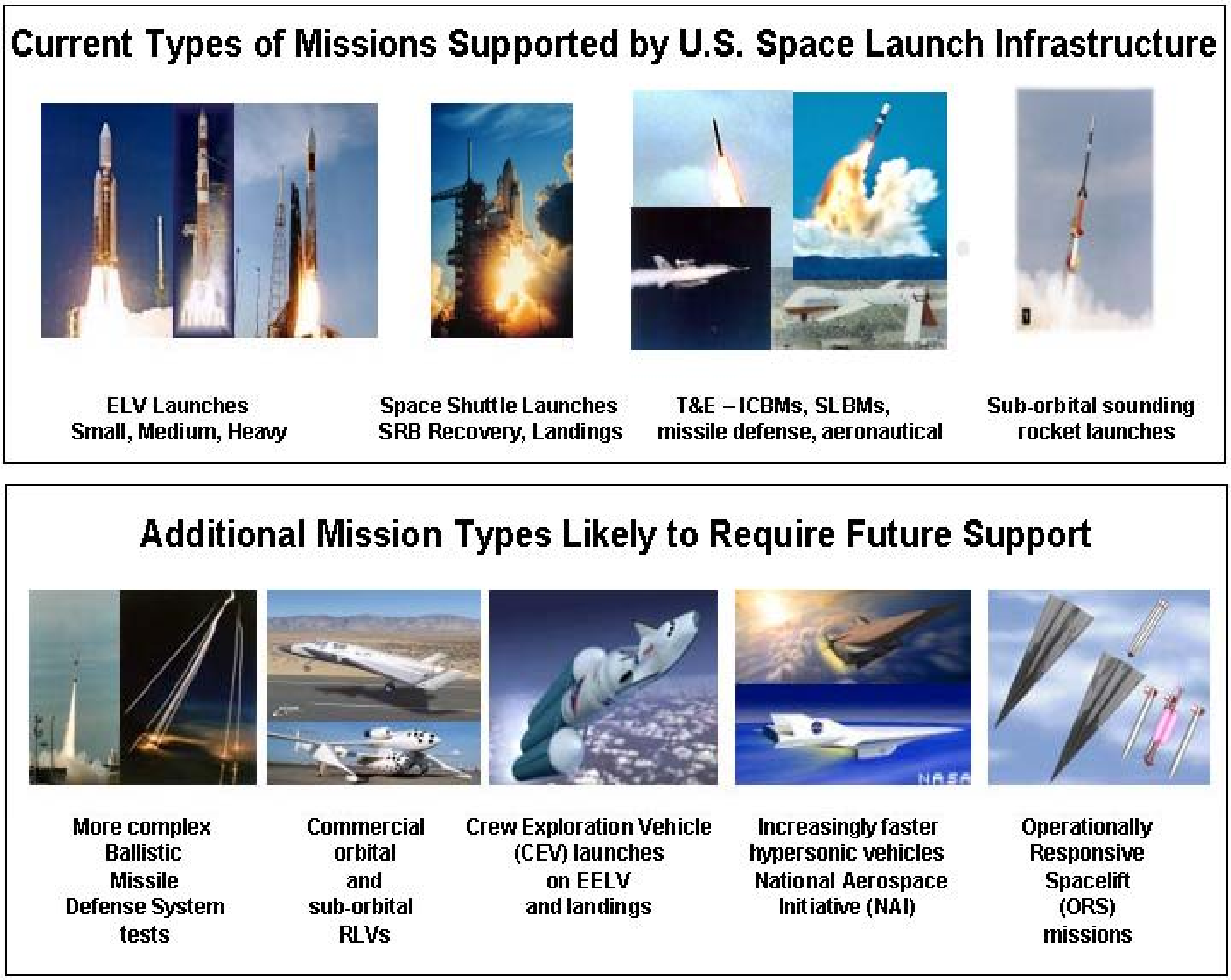
4.0 DESCRIPTION OF ARCHITECTURE

Future spaceport architectures must accommodate the same types of test and operational missions that are supported by today's spaceports, plus a variety of additional missions as described in the Needs Assessment associated with this CONOPS. Figure 4-1 shows representative current and possible future missions driving future spaceport operational requirements.



Source: FIRST Needs Assessment

Figure 4-1 Current and Future Missions Requiring Spaceport Support Infrastructure

The FIRST Needs Assessment also identifies comprehensive operational requirements associated with future civil, national security and commercial missions. These "Level Zero Requirements" include Responsiveness, Global Coverage, Standardization and Interoperability, Safety, Resource Protection, Flexibility and Adaptability, Concurrent Operations, and Optimize Cost. The following paragraphs explain how technological enhancements presented in this section might be expected to advance the Level Zero Requirements and benefit mission operations.

Responsiveness: Technological enhancements discussed in Section 4.0 support improved responsiveness across all spaceport operational areas. Enhancements include implementation of the Spaceport Control Function to co-ordinate local control of all spaceport operational activities at individual spaceports. This will assure more efficient implementation of processing, assembly and integration, pre-launch, and launch operations resulting in more responsive launch capabilities, especially for responsive space launch missions. Also included are automation of many activities previously accomplished manually including vehicle and payload receiving and checkout, component assembly and integration, preflight processing and launch, and recovery/safing/refurbishment. Many of the proposed enhancements will reduce vehicle, payload and systems processing time, reduce time to launch for all missions and expedite on-demand launch readiness. Enhancements will also include implementation of a Central Control Function to interconnect all spaceports worldwide, providing immediate, coordinated response capabilities for on-demand launch from multiple spaceports. Responsiveness enhancements will benefit all programs and missions through increased spaceport launch capacities and reduced processing time required to launch. Mission types enhanced by increased responsiveness would include military/national defense ORS, on-orbit hardware repair, and space rescue.

Global Coverage: The standardization and automation of spaceport infrastructures will facilitate the development of additional spaceports with compatible systems at varying latitudes, allowing flexibility of launch to any azimuth to meet demands for global coverage to serve multiple missions. Additionally, technological enhancements discussed in Section 4.0 will facilitate global deployment and support of proposed vehicle systems and missions through expedited response and delivery, integrated monitoring and condition assessment, and control via the global CCF. Most programs and missions will benefit from enhanced global coverage that affords the capability to deliver a vehicle or payload to any orbit, point in space, or remote surface destination.

Standardization and Interoperability: Proposed technology enhancements and standards development will benefit most programs and missions through improved operational and service efficiencies related to interfaces among flight vehicles, payloads, and supporting spaceport infrastructures. Technological enhancements discussed in Section 4.0 support standardization of vehicle operating systems, components, payload delivery systems, condition monitoring systems and interfaces with spaceport service infrastructures and management functions through the SCF. Enhancements are also proposed for the physical interfaces between flight systems and ground support and maintenance systems to streamline vehicle and component movement, service and maintenance, assembly, integration, and launch activities. All programs and mission types could benefit from standardization to some degree. Programs and missions that would be expected to benefit most from enhancements to standardization and interoperability include those with similar physical and operating characteristics. Additionally, new startup ventures will benefit from reduced subsystem development costs if a set of standardized interfaces are already in place and proven at the spaceports. A few examples include horizontally operating vehicles sharing common service facilities and connections, common payload interfaces and modular payload containers, standardized health monitoring systems and modular service components, vertical launch vehicles sharing common launch platforms and transporters, and standardized launch site quick connections.

Safety: Technological enhancements discussed in Section 4.0 will serve to improve spaceport operations and mission safety. Many of the automated processing and assembly/integration systems proposed will serve to remove human physical interaction from the processes, thereby reducing the potential for accidents and injury. Continual SCF overwatch and analysis of flight hardware, payload, and support infrastructure IHM systems, wherein early detection and resolution of potential problems will avoid the development of more hazardous situations, will also serve to improve operational safety. Self-healing and self-sealing capabilities in flight systems and support infrastructure will reduce the potential for hazardous leaks and resulting corrosive/explosive events. Automatic leak detection and remediation will abate hazardous conditions, should they occur. Automation of launch activities and quick-connect features at the launch site will serve to increase operational safety while reducing hands-on human interaction. SCF and CCF control and monitoring/analysis of launch and flight operations and flight IHM systems will result in the safest possible environment for spaceport operators and crews/passengers during launch and flight activities. All spaceport users will benefit from these enhancements.

Resource Protection: Resource protection will be enhanced through a variety of initiatives proposed in Section 4.0. Automation in all areas of flight system and payload handling, processing, and launch operations will reduce human interaction and facilitate greater security and control. SCF-controlled and monitored vehicle, payload and support infrastructure systems, together with facility security and monitoring systems, will facilitate comprehensive surveillance and control of all spaceport operations and an increased capability for early identification and neutralization of any threat or anomaly that might be identified. The CCF function will serve as the connection between spaceports and will provide communications and security database interconnection for all spaceport security activities. All spaceport users should benefit from these capabilities.

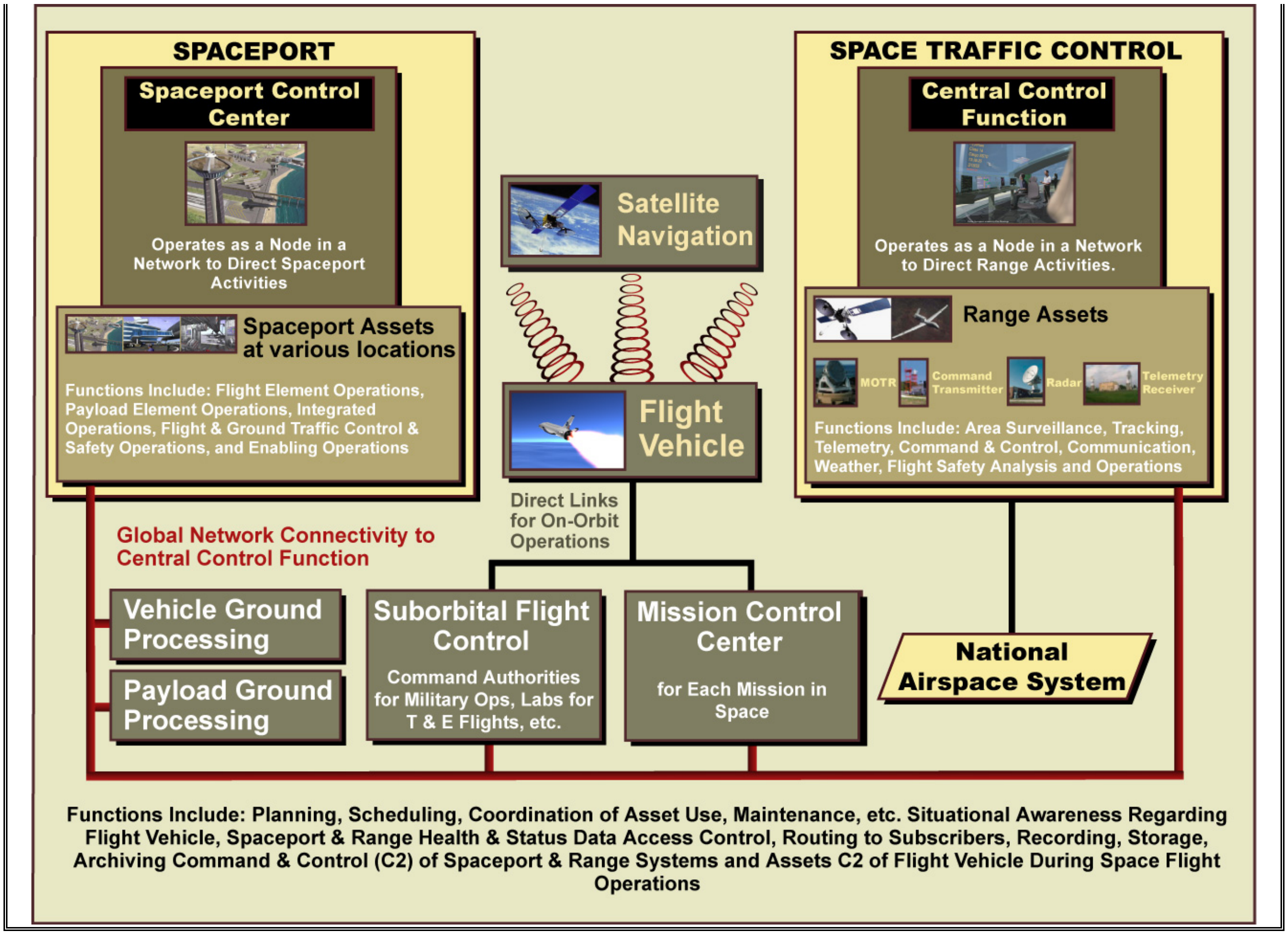
Flexibility and Adaptability: Technological enhancements discussed in Section 4.0 will increase flexibility and adaptability in spaceport program-supporting infrastructures, resulting in reductions in the amount and variety of ground support equipment and facilities needed to support missions. Utilization of adaptable and SCF-controlled automatically reconfigurable equipment to process, assemble, integrate, transport, and launch multiple vehicle types will result in shared use of facilities, shorter timelines from processing to launch and reduced investment in the cost of infrastructure and support services. Vertical launch facilities accommodating most programs will provide standardized quick-connect interfaces with transporters configured to specific vehicle and mission requirements, allowing shorter dwell times at the launch site and higher launch rates per launch facility. Most programs and missions should benefit to some extent from flexibility and adaptability enhancements. Programs with unique flight system components (such as exploration missions) and a relatively small number of unique operations may benefit to a lesser degree than programs featuring many repetitive launches of common flight systems (such as vertical launch payload delivery to orbit).

Support Concurrent Operations: The technology enhancements discussed in Section 4.0 will further concurrent operations capability. Implementation of the CCF system will facilitate coordination between spaceports and between concurrent mission operations at multiple spaceports. The SCF function will enhance mission management capabilities, facilitating more simultaneous mission operations at individual spaceports, through automated flight systems and payload condition monitoring and artificial intelligence analysis of historical databases to control mission activities and respond to and resolve detected anomalies. Spaceport infrastructure and support systems enhancement will facilitate increased spaceport capacity to process multiple flight systems at one time resulting in higher spaceport launch capacities and concurrent launch capabilities. Mission types that would benefit most from concurrent operations capability enhancements would include high frequency/high volume activities such as military/national defense ORS, multi-launch exploration mission campaigns and mass public space transportation/space tourism. However, all mission types will benefit from enhancements to concurrent operations capabilities that increase system capacity thereby assuring on demand access to space for all mission types.

Optimize Cost: Technological enhancements discussed in Section 4.0 will serve to increase system capabilities and operating efficiencies to optimize operating costs throughout spaceport operations. The SCF will assure optimized scheduling and flow of flight elements, payloads, materials, supplies and mission-critical events to improve operational efficiencies throughout thespaceport and reduce service and processing times to launch. Standardized interfaces and servicing procedures will reduce time required for servicing and refurbishment operations and reduce the required investment in spaceport equipment and infrastructure. These enhancements will facilitate more efficient spaceport operations and launch processes, resulting in reduced costs for all spaceport users.

To support new types of space flight operations and associated activities, future spaceport systems must take advantage of an open architecture, interoperability, and standards (as appropriate) to enable the transition of new systems, technologies, and capabilities into operational use as they become available. A short overview of the future space flight operations concept is presented here to provide the system-wide operational framework that spaceports operate within. For an in-depth description of the entire future space flight operations architecture please see the Future Space Vehicle Operators CONOPS document associated with this CONOPS.

The Space Flight Operations architecture consists of a network-centric capability to coordinate and control space transportation assets and activities around the world using a variety of control centers and user facilities connected through a Central Control Function.



Source: FIRST Future Space Vehicle Operators CONOPS

Figure 4-2 Conceptual Architecture to Support Space Flight Operations

As shown in Figure 4-2, the primary elements of the future space flight operations conceptual architecture are:

- Spaceports at various locations, operating as nodes in a global network.
- Global space launch and test range assets, including shared-use satellites and airborne platforms, plus ground-based assets at various locations.
- The Central Control Function—an integrated, centrally-managed, network-centric capability to coordinate support for space flight operations by acting as an information clearinghouse on a global network, and to control spaceport and range assets around the world in support of processing, launch, takeoff, flight, reentry, and landing operations.
- A hierarchy of control centers and associated controllers to manage the various operational aspects of space flights and interface with each other to maintain seamless and safe flight operations throughout all phases and altitudes of the flight, from operations within the National Airspace System to operations beyond low Earth orbit.
- User Facilities, including those that are operated by a flight vehicle owner, a payload owner, command authorities for military operations (like operationally responsive space flights), laboratories and program offices that are conducting test and evaluation, and others as required to support particular space flight operations. In some cases, User

Facilities also support on-orbit operations using a direct interface through a Mission Control Center for particular space flight operations.

- Automated planning, scheduling, coordination systems supported by automated decision support tools to provide course of action options and recommendations based on modeling, simulation and analysis of potential implications.
- A variety of IHM systems including sensor systems, and self-diagnosing, self-reconfiguring, and self-healing vehicle and support systems to provide situational awareness information through the global network.

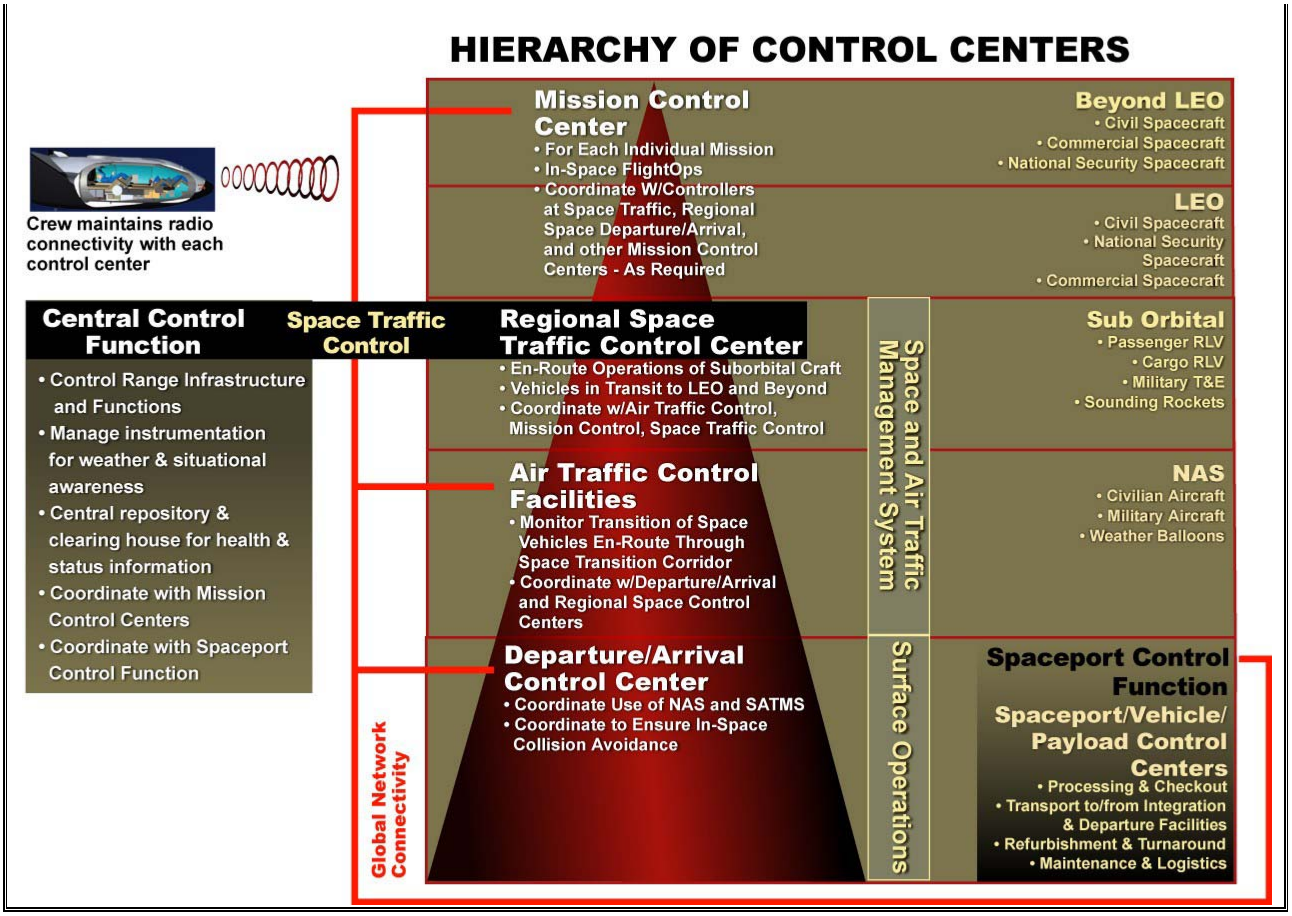
The network-centric Central Control Function (CCF) is at the core of the concept for future space flight operations that are enabled and supported by future spaceports and the envisioned global space launch and test range. It is one of the most fundamental distinguishing features that enable future operations to be conducted more efficiently and responsively than today's systems by enabling concurrent operations and increased operations tempo. Without a Central Control Function, it will be difficult to build an integrated system that coordinates the operations of new and existing users with sufficient capacity to enable and support more ambitious and frequent space launch and flight test activities. The following section provides a brief overview of the CCF.

Central Control Function

The CCF directs and coordinates spaceport and range operations and provides a central clearing house for situational awareness information. Operating as a node within a global network, it provides a variety of services using network-based user interfaces, and automated intelligent decision support systems. Its major focus is directed toward safely and efficiently managing the use and condition of spaceport and range assets, while also serving users' information needs on a subscriber service basis. For an in-depth description of the Central Control Function please see the Future Space Vehicle Operator CONOPS document associated with this CONOPS.

Space flight operations rely on a distinct set of functions accomplished by a hierarchy of control centers and controllers. These control centers and controllers manage the various aspects of space flights and interface with each other to maintain seamless and safe operations throughout all phases of a space flight operation, including ground operations and the transitions through the National Airspace System on the way to and from space. The control centers are linked through a global network to facilitate interfaces through the Central Control Function. Spaceports are the activity centers, or nodes in the global network, where most surface operations are performed.

The future space transportation system architecture relies on a hierarchy of control centers to conduct safe, reliable, and routine space flight operations.



Source: FIRST Future Space Vehicle Operators CONOPS

Figure 4-3 Hierarchy of Control Center Functions

As depicted in Figure 4-3, in addition to the Central Control Function, there are five different types of control centers involved in managing the operation of space flight vehicles and their payloads, cargo, and passengers:

- Spaceport Control Function (SCF) control the pre- and post-flight processing and checkout of flight vehicles and payloads, along with movement between facilities, and maintenance and logistics between flights.
- Departure/Arrival Control Centers (DACC) coordinate range support, use of the National Airspace System (NAS), and information on collision avoidance with objects in space for departing and arriving flights.
- Air Traffic Control Centers (ATCC) coordinate and manage use of the National Airspace System (NAS) to ensure that space flight vehicles transiting the NAS on the way to or from space can be safely integrated with scheduled air traffic.
- Regional Space Traffic Control Centers (RSTCC) monitor, coordinate and manage flights to, through, and from space, to ensure that flight vehicles operating in or through space can be safely accommodated along with other vehicles flying in space, while avoiding debris hazards.
- Mission Control Centers (MCC) for space flights that include operations in orbit, include dedicated links for voice, video, and data connectivity to flight vehicles to provide

tracking, telemetry, and commanding for national security, civil, and commercial satellites, deep space probes, and crewed missions in orbit, to the Moon, and beyond.

The SCF will be the centerpiece of spaceport management systems, interconnecting, coordinating and directing every aspect of spaceport operations. The SCF will be able to implement the spaceport operating plan efficiently in that continual monitoring and control of plan parameters will be possible. The effect of technology enhancements will be realized most significantly from a management perspective in the capability of the SCF to receive and respond to real time data supplied from sensors and IHM systems integral to a broad range of spaceport infrastructure components, operating systems and equipment. SCF interfaces will be highlighted within each of the five spaceport operational phases: Flight Element Operations (4.1), Integrated Operations (4.2), Payload Element Operations (4.3), Flight & Ground Traffic Control & Safety Operations (4.4), and Enabling Operations (4.5). For more information and background on the generic spaceport operations model including spaceport functions and subfunctions please see the Advanced Spaceport Technologies Working Group (ASTWG) Baseline report.

4.1 Flight Element Operations

Flight element operations are all activities associated with receipt, acceptance, handling, assembly and checkout of flight vehicles and components shipped to the spaceport as-well-as postflight operations for vehicles and vehicle components returning to the spaceport at the conclusion of a launch or mission.

Receive Flight Elements, Assemble Flight Elements and Checkout Flight Elements

Common areas will be used for receiving, acceptance, and tracking of all vertically and horizontally launched flight elements arriving at the spaceport. It is intended most vertically launched flight elements would be checked in at a common receiving and acceptance operation. Some elements, due to extreme size or operating characteristics, would be checked in at locations specific to their use or operation. These would include some super-heavy launch vehicle components and most horizontally operating reusable flight elements, which would arrive at the spaceport as assembled units (assumes individual stages of multi-stage vehicles arrive separately).

It is envisioned all flight elements delivered to the spaceport will contain Radio Frequency Identification (RFID) chip information for identification and Integrated Health Management (IHM) systems to monitor and verify flight element condition and system status. Each flight element will be scanned upon arrival to register its receipt and ascertain its operational status at time of delivery. In conjunction with appropriate vehicle or payload control centers, the SCF tracks all movements to and within the spaceport by using a Precision Local Positioning System (PLPS). Encoded documentation received with the flight element and scanned into the SCF database upon delivery would provide all necessary information regarding the planned launch as well as handling procedures, servicing requirements, specifications, trouble-shooting and other pertinent information. This information becomes part of the SCF database, which allows the spaceport to schedule all pre-launch activities and operations necessary to support the planned launch. The SCF also applies an AI analysis of operational status data with previously stored operational and service information in support of flight element pre-launch handling and checkout to verify condition at the time of arrival at the spaceport, recognize problems, and recommend solutions based on past performance. If a potential problem is detected, the SCF will interact with service operations to remedy the anomaly, or if necessary, notify the operator and identify the appropriate remedy procedure. Vehicle status data maintained by the SCF is also accessible in real time to the operator.

Parts and component receiving, acceptance, and inventory control is another operation envisioned to be accomplished by the common receiving and acceptance function and controlled by the SCF. The model envisions supplies, parts and component receiving and acceptance being integral with the vehicle receiving function with one parts inventory and control operation serving most spaceport programs and missions. While most parts and components are maintained in a common inventory location, it is likely some parts and especially large or unique components would be ordered and received through the common check-in operation and forwarded directly to program operations for storage and use.

After receipt and acceptance, flight elements are transferred via automated transporters for delivery to flight element assembly and checkout operations. Vertical launch vehicles are forwarded to a common vertical vehicle assembly and checkout operation. Most super-heavy components are scanned, accepted and handled at dedicated program facilities where specialized handling equipment is available and assembly and checkout would occur. Horizontal launch vehicles and flight elements are scanned and accepted at their arrival location and transferred by automated tug directly to the common horizontal vehicle service and maintenance operation for checkout prior to being entered into service.

Upon arrival at the flight element assembly and checkout operation, flight elements are delivered to a pre-assigned assembly bay, reserved and configured to vehicle specifications by the SCF-controlled program scheduling and operational control function. Depending on whether assembly and integration are to be accomplished horizontally or vertically, flight elements will be assembled either on a vertical integration launch platform or a horizontal integration launch platform erector. Components are engaged by lifting and positioning equipment and staged into the assembly bay, positioning and mating the flight elements employing a PLPS-based automated positioning system as it progresses through its automated SCF programmed component assembly plan. Automated standardized robotic quick-disconnect umbilicals facilitate connection to the launch platform and flight element servicing. The SCF continually monitors wireless transmissions from the flight element IVHM system verifying vehicle status as robotic stations perform assembly and checkout activities as directed by the automated assembly and checkout plan. Stereovision helmets and heads up displays communicating with the SCF AI database through wireless interface and remote sensors support activities requiring human interaction. Information provided includes vehicle specifications, diagnostic analysis and support, and recommended servicing and checkout procedures.

At the completion of checkout (or other time appropriate for the specific mission), the assembled launch vehicles and launch platform/carrier erector move to program integration operations (or to the designated launch site if integration is to occur at the launch site).

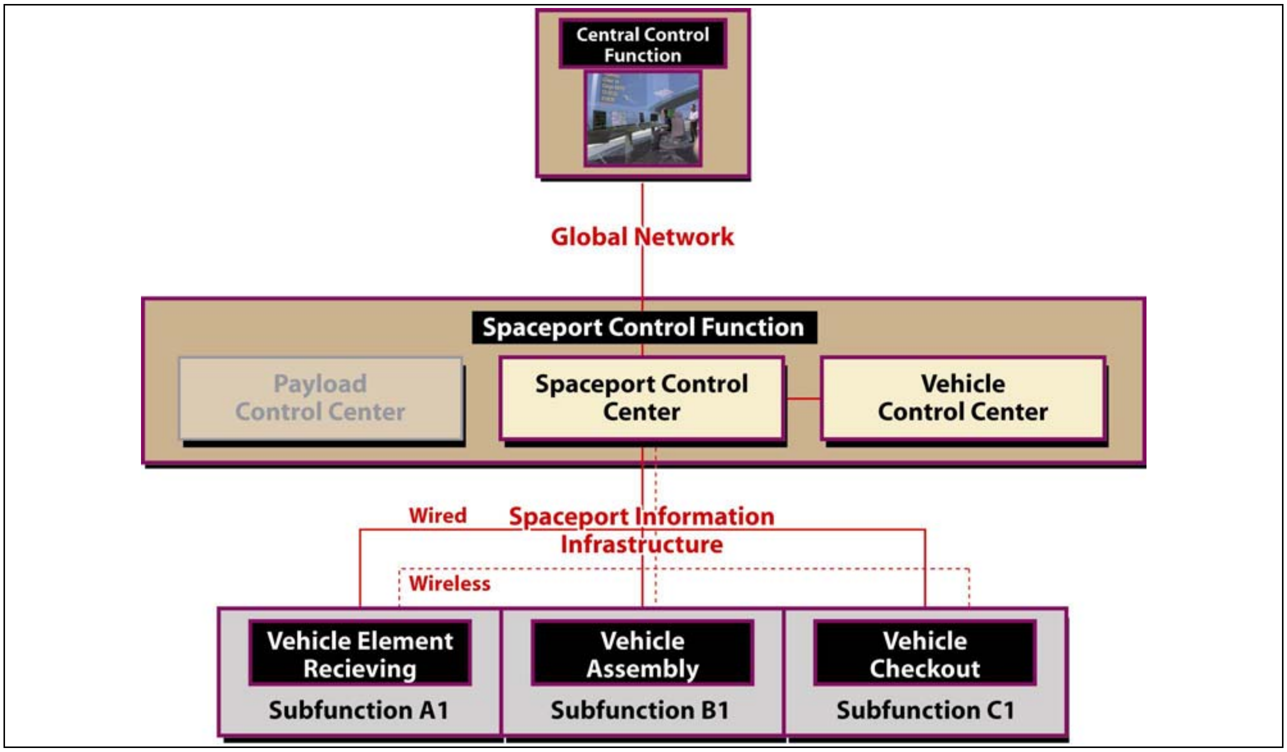


Figure 4-4 Flight Element Receiving, Assembly and Checkout Relationship Diagram

<u>Prepare Flight Elements for Turnaround and Payload Removal, Prepare Payload Elements for Turnaround, and Restore Flight Elements</u>

From the recovery activity, flight elements (vehicles and components with payloads or payload containers as applicable) are forwarded along one of the three processing "tracks" to the appropriate returning flight element processing area for vertical, super-heavy or horizontal vehicles. These activities include anomaly identification and resolution through evaluation of vehicle and payload IHM system data transmitted to the SCF, if not accomplished at the recovery site, vehicle disassembly (where applicable) with expendable components processed for disposal and reusable components processed for restoration or servicing. Additionally, depending on the returning vehicle's mission, various down payloads or empty payload containers may be removed from the vehicle for forwarding to down payload processing within the centralized payload operation.

Returning flight elements are forwarded to the processing activity via robotic tugs or transporters as described previously. Acting on data scanned at the landing/recovery site, the SCF has alerted the appropriate processing facility to the pending arrival of the vehicle or components, reserving a place in the processing queue and pre-setting service and handling equipment interfaces to the appropriate vehicle or component specifications. When the flight element arrives at the processing location the preset interface and handling infrastructure engages the flight element and, directed by the element-specific SCF processing program, activates the PLPS-directed robotic handling and/or disassembly operation. Activities at this juncture would also include automated quick disconnect and de-integration of down payloads and modular payload containers. Any anomalies not resolved at the recovery site are evaluated and resolved via IHM data analysis and vehicle/payload scans. Separated elements, previously scanned for condition and disposition, are transferred to robotic tugs or transports for relocation to the appropriate restoration or disposal operation.

Horizontally operating vehicles requiring only quick turnaround service before the next flight are positioned by the transport device for payload container/down payload removal. SCF programmed robotic payload extractors preset for the appropriate payload/container configuration remove the modular payload container/payload from the flight element and place the container/payload on a PLPS-guided pallet or transporter for transfer to the payload processing operation for payload disposition and container refurbishment. The flight element is then transferred via automated tug to the quick turnaround servicing operation. Horizontally operating flight elements requiring restoration or scheduled off-line maintenance are forwarded to flight element restoration or offline maintenance.

Vertical launch and super heavy launch flight elements (vehicles and reusable components) are forwarded from return processing to their respective vertical and super-heavy vehicle restoration operations. Reusable horizontal launch vehicles requiring restoration or off-line maintenance are forwarded to a common restoration operation for the necessary repairs before being returned to the in-line service function. Restored vertical launch flight elements are forwarded to the appropriate vertical or super-heavy vehicle assembly area.

Common payload processing facilities and equipment serve most up and down payloads, missions and programs. Down payloads and returning payload containers would be removed from the flight element and processed for disposal, shipping to off spaceport locations, return to other spaceport activity centers, or restoration. In the first era, down payload activity relates primarily to returning Space Shuttle and ISS program payloads, equipment and experiments. As new reusable vehicles and programs evolve in the second and third eras, the volume and variety of down payloads is anticipated to expand significantly. Vehicles with modular payload bays will carry interchangeable modular containers with scientific or intelligence-gathering equipment, various payloads or munitions delivery systems. Satellites and other flight elements may be recovered and returned from orbit and on-orbit servicing modules may be utilized. Probes and vehicles will return with materials from space. These payloads will drive the need for expanded down payload extraction and processing facilities.

Current vehicle restoration activities relate primarily to the Space Shuttle vehicle and SRB components, and certain test activities. The introduction of reusable vertical and horizontal launch vehicles is anticipated to significantly increase vehicle restoration activities from current levels, although advances in vehicle materials and technologies in the longer term are expected to reduce the extent, frequency and time required for vehicle restoration activities. The spaceport can further expedite the flight element restoration process by implementing common restoration operations with automated, standardized service interfaces and handling equipment to service multiple vehicles and programs in one location. It is envisioned the SCF would schedule restoration activities for each flight element based on wirelessly transmitted scan data obtained from the element's IHM system at the time of return to the spaceport recovery or processing operation. The SCF would also implement scheduled maintenance procedures based on AI analysis of the historical operations database and failure-predicting trend analysis algorithms. Pre-programmed, PLPS-positioned automated servicing and positioning infrastructure would engage flight elements delivered to the restoration operation via automated tugs. Element-specific SCF-controlled maintenance programs and component replacements would be accomplished by robotic applications to the greatest extent possible. When human service interaction is necessary, technician service equipment would include PIPs with wireless interface with the SCF AI database and hands-free heads-up displays providing vehicle specifications, diagnostic analysis and support, and recommended service procedures to accomplish repairs and restorations.

At the same time the SCF initiates scheduling of restoration and maintenance activities, it also requisitions and schedules delivery of all required replacement modules, components, parts and supplies from the fully automated central parts inventory operation. Ordered parts and supplies are robotically retrieved and delivered to the appropriate maintenance location by automated delivery system directed by the SCF. The SCF also controls the parts and supplies inventory, anticipating need based on analysis of the database of all vehicles operating at the spaceport, considering upcoming scheduled maintenance events, AI-projected maintenance requirements based on historical systems maintenance and failure analysis, and direct input received from IHM scan data. As parts and supplies are withdrawn from inventory for use, SCF automatically orders inventory replacement.

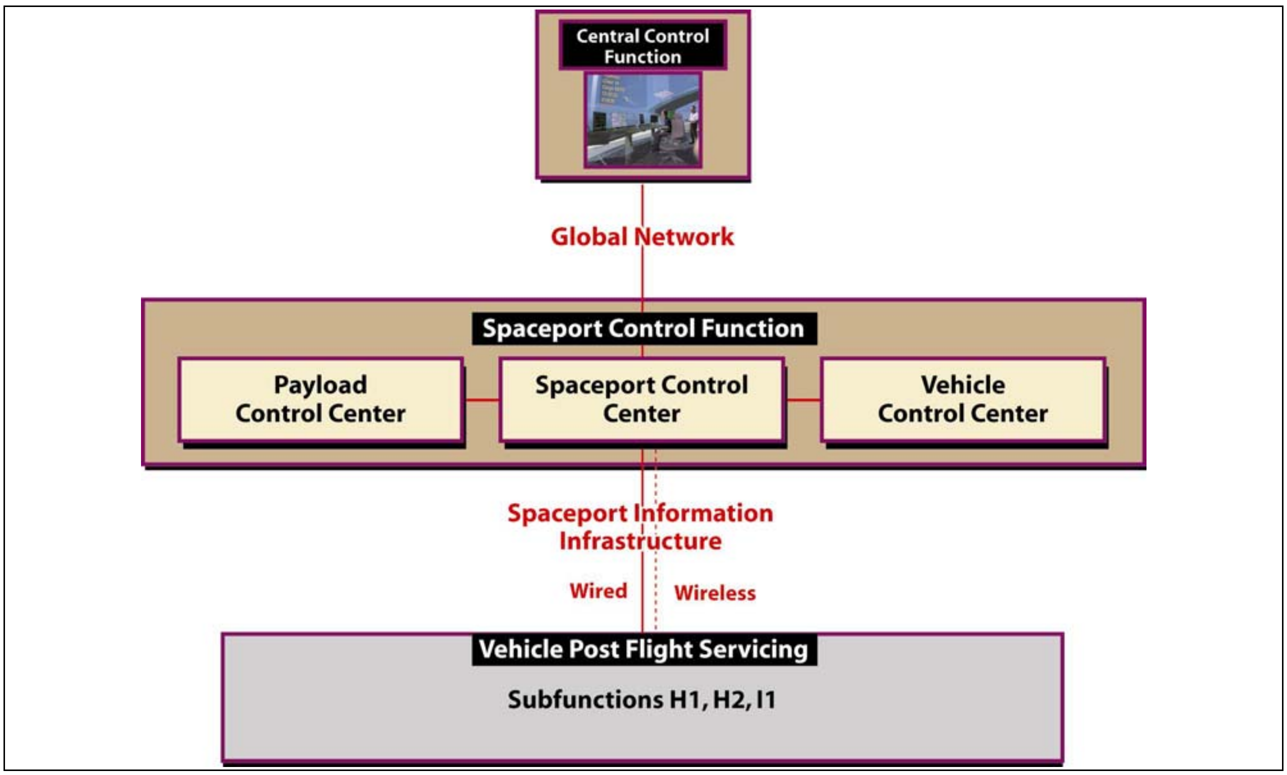


Figure 4-5 Vehicle Post Flight Servicing Relationship Diagram

Quick Turnaround Vehicle Diagnostics and Servicing

Returning reusable launch vehicles not requiring restoration or scheduled maintenance are forwarded from return vehicle processing to quick turnaround vehicle diagnostics and servicing. The quick turnaround activity is expected to emerge at spaceports with the introduction of reusable launch vehicles sometime in the late first or second era and will evolve as launch vehicles become more technologically sophisticated. The activity described here-in relates primarily to robust later second and third era vehicles evolved to the point of requiring minimal servicing between flights. Those vehicles, which will be engineered to complete numerous flights between restorative maintenance operations, operate horizontally and will have integrated vehicle health monitoring (IVHM) systems to facilitate a quick systems check and routine servicing for immediate return to service.

Common servicing is envisioned for horizontally operating vehicles. A common operation for vertically operating reusables could be developed separate from vertical vehicle maintenance and restoration if justified by the number of operations. Horizontal vehicles will arrive at the quick turnaround service operation, delivered by automated tug or integral tow device, controlled by the SCF and positioned by PLPS. A service position for the returning vehicle will be reserved in advance by the SCF based on scheduled vehicle return time and confirmation of vehicle return at the landing/recovery location. Scan of the vehicle at the recovery location and SCF receipt of wireless transmission of vehicle condition and service status from the on board IVHM system facilitate SCF and AI database analysis of vehicle condition and the development of a service program specific to each returning vehicle. Service supplies and parts/modules are automatically requisitioned from the automated parts inventory and are delivered via automated delivery system on a just-in-time basis to the designated service location.

When the flight vehicle arrives for quick turnaround service, it is engaged by a pre-positioned automated service transporter, which the SCF has programmed to adjust to vehicle interface specifications, maintained in the AI database. The transporter will move and position the vehicle employing an automated positioning system as it progresses through its SCF programmed service plan. Automated standardized robotic quick-disconnect service connections will facilitate replenishment of serviceable fluids. The SCF continually monitors wireless transmissions from the vehicle IHM system verifying vehicle status as the service operation progress. As the transporter moves the flight vehicle, robotic stations perform automated service module/component replacements as directed by the automated service plan. For operations requiring human service interaction, technician service equipment includes stereovision helmets and heads up displays through wireless interface and remote sensors with the SCF AI database providing vehicle specifications, diagnostic analysis and support, and recommended servicing procedures to accomplish the required service activities. When service operations are completed, the automated transporter returns the flight vehicle to its freestanding position where it is engaged by an automated tug for transfer to a separate location for payload integration.

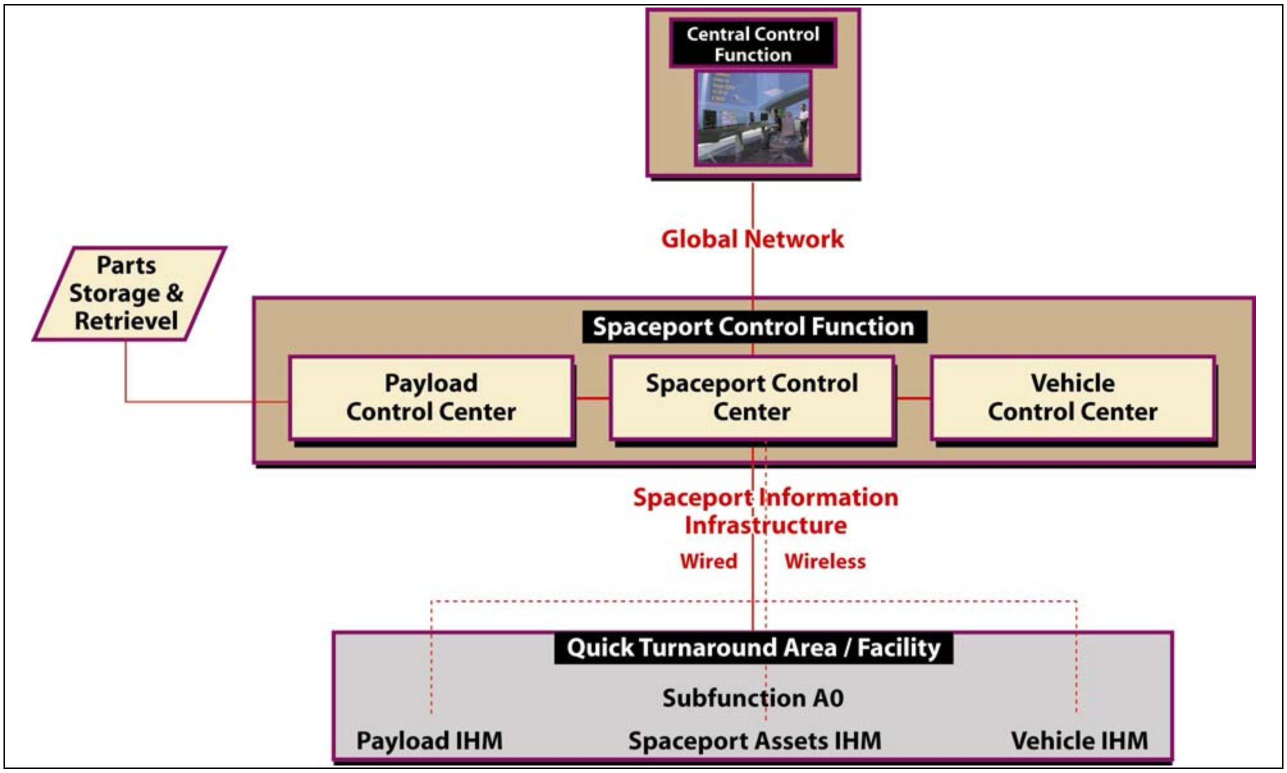


Figure 4-6 Vehicle Quick Turnaround Relationship Diagram

4.2 INTEGRATED OPERATIONS

Integrated operations are activities related to the assembly of vehicle and payload elements, preparation for and subsequent vehicle launch, flight and mission activities, and return and recovery of vehicle and payload elements.

Integrate Flight System and Payload

Common integration operations are envisioned for all vehicles within each launch mode: vertical, vertical super-heavy, and horizontal vehicles. Separate integration operations are designated for vertical and horizontal vehicles receiving munitions payloads, presumed to be physically removed and secured from other common integration activities for safety and security reasons. It is assumed in the future most payloads will be containerized and that containers will be standardized and modular for most vehicle applications.

The flight element/payload integration operation could be accomplished by various operations and in different ways depending on the type of flight vehicle, vehicle orientation during integration (horizontal or vertical) and physical location (assembly facility, integration facility or launch pad). It is possible vertical launch vehicles (including super heavy launch vehicles) could be integrated with payloads as an extension of the assembly and checkout function, or be moved with the mobile launch platform or platform/erector to another location, either an integration facility or the launch site. Horizontally launched vehicles could similarly receive payload containers as a final step in the quick turn service process, or as a separate operation. For the purpose of this discussion, it is assumed the assembled and checked out flight element has been mated with a launch platform, transporter, or tug, and has been moved to the designated integration position.

Regardless of location or sequence of payload/container insertion, automated container insertion equipment will be required to transfer the container from the transporter to the vehicle. It is also assumed SCF-controlled insertion equipment will be programmable and capable of automated reconfiguration to serve multiple vehicles of the same launch mode (horizontal launch, vertical launch vertically integrated, vertical launch horizontally integrated, super heavy) but also that different modes will require different insertion equipment, resulting in more than one and possibly several insertion operations, as determined by the number of different launch vehicle modes utilized at the spaceport.

As previously stated, it is assumed payloads will be containerized and fully self-sufficient at the time of delivery for integration, thereby reducing environmental and physical constraints on integration operations. At a time appropriate to the launch program schedule, the SCF will initiate automated retrieval of the containerized payload from payload processing/staging at the common payload processing operation or special program area. An automated container transporter controlled by the SCF and guided by PLPS will retrieve the container from its designated holding position and move it to the scheduled integration location. The SCF will continually monitor payload condition and status during transport via wireless transmission of data from the container's IHM system. When the transporter arrives at the integration location, the payload container will be transferred to payload container-to-flight-element insertion equipment, which has assumed the pre-programmed insertion position with respect to the flight element as directed by the SCF from flight element data on file with the launch program. Acting on direction from the SCF, the PLPS-directed insertion equipment inserts the container into the vehicle and activates the structural vehicle-to-container and service/support systems quick connections. Vehicle and payload IHM systems confirm successful completion of payload container integration via wireless transmission to the SCF.

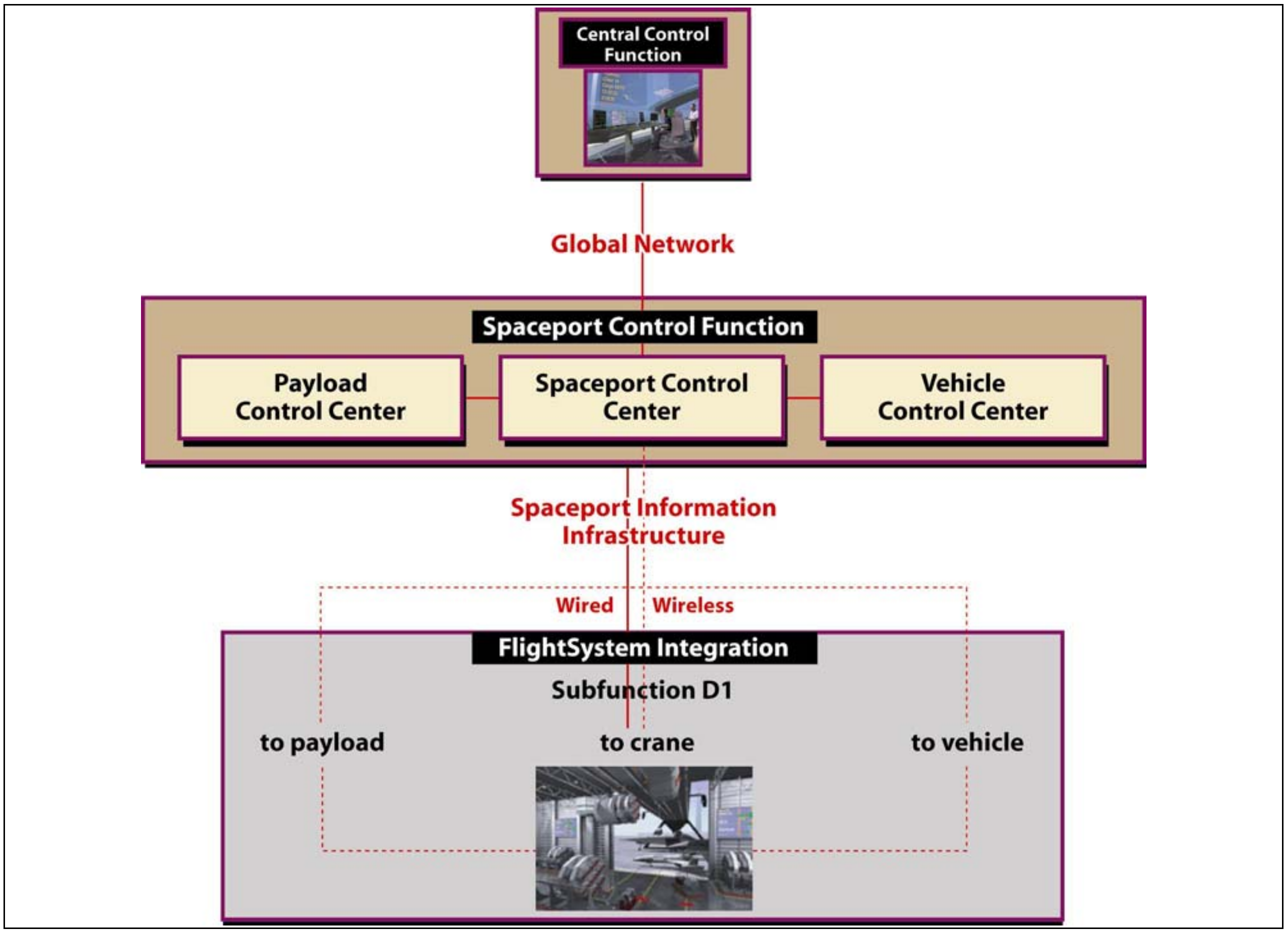


Figure 4-7 Flight System Integration Relationship Diagram

Crew Processing and Passenger Processing

Separate activities with provision for some common services are provided for crew and passenger processing. Operations would include transport of returning crew / passengers from the recovery location to the spaceport pre/post-flight processing activity and delivery from there to the launch site/flight element for departing crew / passengers.

Services provided will vary with the mission served and the era under consideration. Mission activities for Lunar and Mars programs will be rigorous and crew related. First and second era space tourism programs will need to accommodate passengers in addition to crew, and some pre-flight preparation and instruction are anticipated. In the third era, mass public space transportation activities are expected to become routine to the extent the need for specialized training and preparation will not be required, as with commercial air travel today. However, it is also anticipated mass public space transportation flights will be more rigorous for passengers than current commercial airline operations with at least some basic passenger health screening required.

For training activities, it is envisioned the SCF will maintain and administer an extensive database of training resources available for crew, passengers, program and spaceport workers. Crew training could include vehicle/equipment-specific training and education based on data received with the element at check-in and stored in the training database, flight training, simulation and certifications. Passenger training could include instructional information related to pre-flight preparations, the flight experience and utilization of any equipment that may be required during the flight/mission. Mission and spaceport workers could receive training in vehicle utilization, maintenance and repair to facilities systems operation and maintenance. The SCF will automatically advance-schedule training activities to coincide with scheduled flights and missions, and will constantly monitor advances in all related subject matter areas to update training programs to provide the most current information.

Health services that may be provided include personal health and condition monitoring, health screening, and location tracking. The SCF will support and facilitate health screening and monitoring via an AI health conditions and measurements database allowing analysis of readouts wirelessly transmitted from personal health and condition monitors. The monitor devices would be worn by each passenger and crew member and would be capable of sensing vital signs including heart rate, respiration rate, blood pressure and similar condition and stress-sensing data. The device would also serve to indicate the location of each person for the duration of the mission.

Transportation to and from the flight vehicle and passenger/crew support facilities is provided as part of the processing function. The configuration of transport means will depend on the type and orientation of flight vehicle and required separation of vehicle from support operations.

Security screening will be an important consideration, especially as passenger operations become more frequent. The SCF will interact with established international security and screening databases to establish security clearance for each passenger upon scheduling a seat. Upon arrival at the departure location, identity verification will be accomplished by the SCF-facilitated connection to worldwide security databases and personal identification sensors.

Other services that may be required depending on operation type could include passenger receiving, holdroom/waiting, baggage/cargo handling and processing, concessions, overnight accommodations, and equipment issue. Crew facilities would be similar with some services combined for crew and passengers.

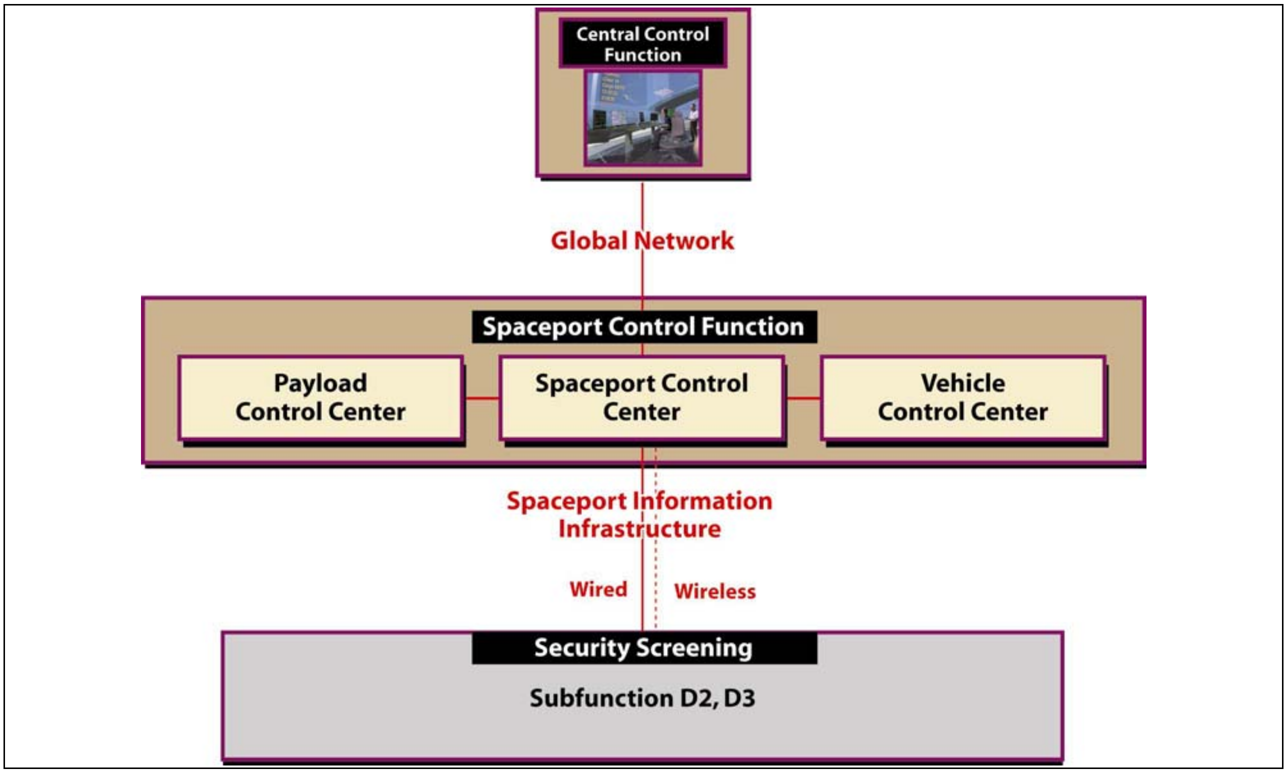


Figure 4-8 Crew & Passenger Processing Relationship Diagram

Execute Departure Operations, Launch and Restore Ground Systems for Reuse

Four different departure facility configurations are anticipated, related to the three vehicle processing “tracks”: two for vertical launch applications (a clean pad with minimal infrastructure and a conventional pad with infrastructure), a specialized pad with extensive infrastructure for super-heavy vertical launch (the most likely vertical operation to serve crewed exploration missions) and a horizontal launch complex. Present spaceport operations implement all four of these configurations, although current horizontal launch activities are limited to conventional aircraft operating as a carrier or first stage of an air-launch or test drop mission. Introduction of new vertical launch vehicles, especially those carrying small payloads to orbit in the commercial market may generate an increase in need for clean pads or pads with minimal infrastructure (first era). Developments in vehicle technologies for space exploration utilizing super-heavy launch vehicles will drive requirements for super-heavy launch facilities (first and second eras). Testing and development of horizontally operating vehicles followed by evolving operation will generate a need for new horizontal launch operations (second and third eras). Departure facilities are intended to accommodate multiple vehicle configurations. For vertical launches, opportunities exist for application of technologies and vehicle transport system enhancements that allow launch transport platforms with vehicle-supporting infrastructures to deliver different vehicle types with different launch facility interface requirements to one clean-pad (minimal infrastructure) facility with standardized, quick connections. More detailed separate discussions follow for horizontal and vertical launches.

Horizontally launched vehicles will taxi to the pre-launch location or be towed by a PLPS-guided tug. The vehicles will be fully serviced and ready for propellant loading and launch. Propellant loading will be accomplished by automated quick-connect fueling station with integral hazard detection and management system to standardized vehicle fueling ports. The SCF will control the propellant loading operation with propellant type, flow rate and quantity determined by AI analysis of vehicle and mission data. After loading, the vehicle will move to a separate staging area where consumable provisions and payloads will be on-loaded, and crew and passengers, if any, will embark. The vehicle will then taxi or be towed to the launch facility.

Vertically launched vehicles will be transported to the launch pad location on a launch platform carrier/erector as described for the vehicle assembly and integration operation. At the appropriate pre-launch time, the SCF will activate the transport process to move the launch platform and vehicle to the designated launch location. Upon arrival, the SCF will initiate automated connection of the launch platform to launch pad infrastructure utilizing quick connects with self verifying and self-healing capabilities. Automated propellant loading will be accomplished by the SCF as described for horizontally launched vehicles.

The SCF will constantly monitor and analyze the condition and status of vehicle, payload, supporting infrastructure, and airspace data received from the CCF throughout the pre-launch process by means of wireless transmissions from IHM system sensors and AI database analysis. In the event a problem is detected during preparations for launch, SCF analysis will determine the appropriate course of action, and initiate a countdown hold if necessary. At the same time, the SCF will automatically evaluate mission parameters and launch schedules to determine the allowable extent of delay at the launch site before the mission must be postponed or other scheduled launches will be adversely affected. Pursuant to that effort, the SCF will re-schedule subsequent launches to other launch sites, if possible. The SCF will direct any necessary repairs or restorative actions through interface with self-healing and IHM systems, robotic interfaces, and AI database-assisted human involvement, as necessary. If AI database analysis indicates repairs can be accomplished within the available time window, the SCF will initiate repair activities. Should repair at the launch site not be possible, the SCF will terminate the launch preparations sequence and initiate an automated launch sequence abort program, safing the vehicle and payload, off-loading propellants and passengers, and initiating disconnect from the launch site and tug/transporter return to the launch vehicle staging or repair area.

At the completion of launch activities the SCF will automatically initiate a sequence of restorative activities to replenish depleted support systems and restore support facilities to a state of launch readiness for the next scheduled launch. For horizontal launches, the PLPS-guided tow/tug device will return to the processing/integration location to position the next vehicle. For vertical launches, the SCF will initiate PLPS-guided launch platform quick disconnect from pad infrastructure and return to the integration facility to receive the next launch vehicle. If the platform requires restorative work IHM sensors on the platform will provide information to the SCF, which will schedule and initiate repairs at a location removed from the launch pad. Self-healing and sealing systems will automatically respond to many detected problems. Launch pad or horizontal launch facilities will be equipped with self-scanning/clearing capability to scan their facilities and remove any residual launch debris. Launch facilities will also be equipped with sensors monitored by the SCF to detect any environmental hazards. Upon detection, the SCF will analyze the condition, implement the appropriate automatic remediation action, and effect cleanup and disposal of the hazardous material. The SCF will also initiate replenishment of reserve tanks and resources at the launch site, in predetermined quantities as specified in the AI database for the next scheduled launch.

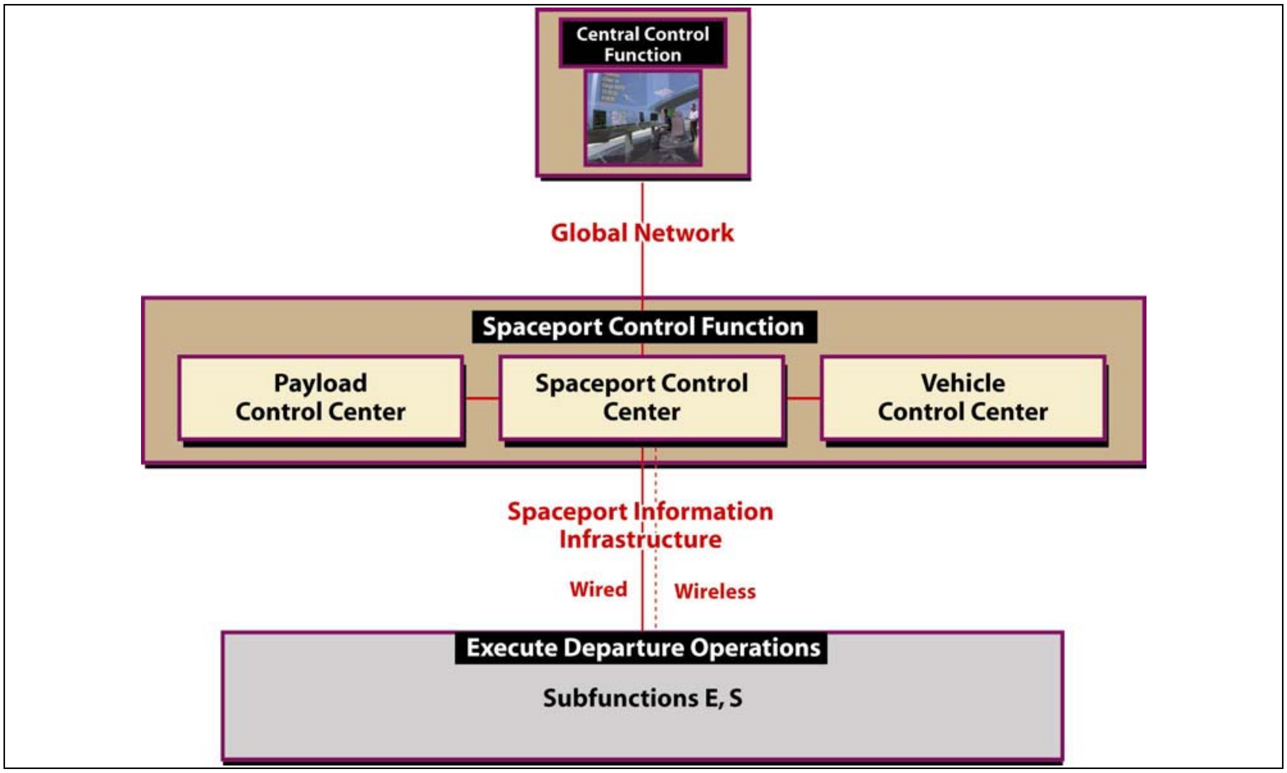


Figure 4-9 Departure Operations Relationship Diagram

Monitor and Manage the Flight

Flights will be monitored and managed by three entities, each of which will have unique responsibilities with regard to certain aspects of the flight/mission. Intercommunication between the managing entities will be critical in providing comprehensive flight management services. The CCF will monitor in-flight activities between spaceports, including flight path/trajectory verification and routing, schedule adherence and vehicle/payload condition and emergency situational response and resolution. The SCF will receive in-flight data from the CCF as well as spaceport systems data from support infrastructure and environmental sensors at the spaceport. The SCF will direct all spaceport support infrastructure systems in response to operational data received from the CCF and will continually update the CCF as to spaceport operational status. Vehicle Control Centers (VCC) and Payload Control Centers (PCC) include management and control activities specific to the flight elements, payloads and the activities comprising each flight/mission. The VCC & PCC will monitor vehicle and payload condition and mission status and will control the operation of the flight elements. The SCF will continually transmit status and condition data to the CCF and SCF for monitoring and response to events as they arise.

The SCF will maintain the spaceport in a constant state of readiness to accommodate scheduled and unscheduled vehicle recoveries as confirmed to the SCF by the CCF. Through wireless transmissions received from the vehicle IHM systems, the VCS and CCF will continually monitor vehicle condition to confirm nominal vehicle operations and identify any emerging operational anomalies that could result in early mission/flight termination and emergency return to any system spaceport. Should this occur, the CCF would clear an appropriate path for the returning vehicle and notify the appropriate destination SCF, which would activate all necessary spaceport emergency response and recovery procedures and operations to accommodate the returning vehicle.

The CCF will monitor the health and progress of all active flights and scheduled departures and arrivals, confirming and adjusting schedules when necessary. The CCF will transmit health and schedule information to the SCF, which will coordinate supporting ground recovery equipment and infrastructure to meet actual flight timing, initiating emergency recovery activities if necessary and scheduling post-arrival vehicle/payload recovery and turnaround activities.

The SCF will constantly monitor data transmitted from spaceport environmental weather sensing equipment and facility condition and status sensors to assess and report to the CCF the operational status of the spaceport and availability to accept scheduled and unscheduled landing/recovery operations of flights originating from other spaceports.

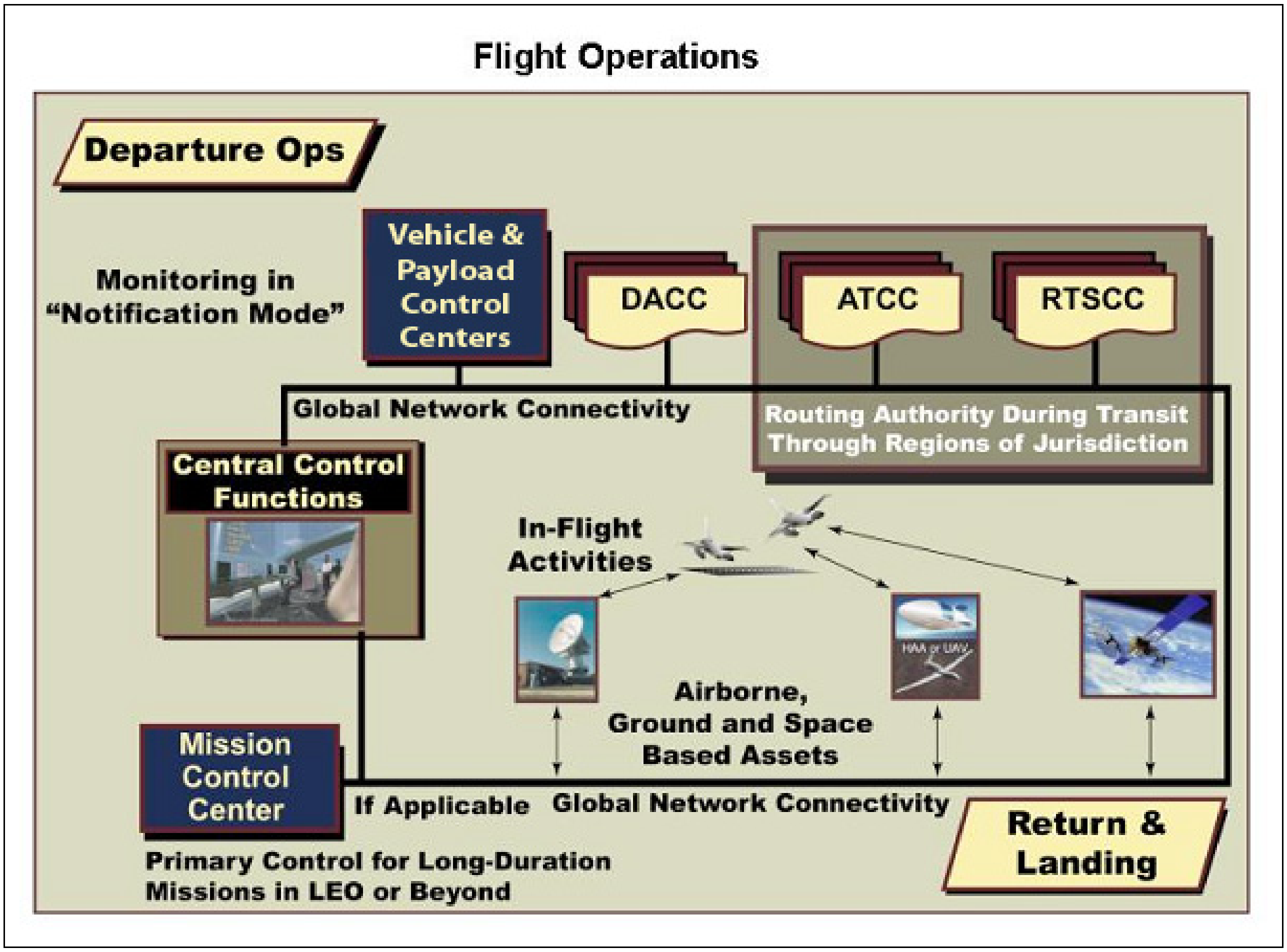


Figure 4-10 Mission Operations Relationship Diagram

__Landing / Recovery Operations and Land / Recover Flight Elements and Payloads__

Landing and recovery operations are comprised of vertical and horizontal recovery options. Spaceport recoveries are limited in the first era with a high percentage of expendable vehicles in use. Reusable vehicles and components currently in use include air-launch carrier aircraft for launch vehicles like Pegasus, elements of the Space Shuttle program, and returning horizontal vehicles/test beds related to testing and development activities. The anticipated development and introduction of new vertical launch and horizontal launch reusable vehicles is expected to significantly increase the number of recoveries with a variety of recovery modes. In addition to horizontal and vertical recoveries at the spaceport, some recoveries will occur at locations removed from the spaceport, including open land and water recovery sites, requiring remote recovery operations, specialized recovery equipment and even port/wharf facilities and specialized recovery vessels. To the extent return and recovery modes for evolving programs can return to the spaceport and adopt common return operational profiles, the potential for commonality of spaceport recovery operations will be enhanced. As horizontal launch and recovery vehicles become operational and evolve it is anticipated horizontal recoveries will comprise a significant majority of total spaceport recoveries, thereby presenting greater opportunities for common recovery and handling operations and related evolved technology applications.

It is envisioned landing vehicles will be equipped with automated landing control systems in constant communication with the destination spaceport/landing area SCF and related GPS locator. All evolved vehicles (and payloads or empty payload containers if any are on board at the time of recovery) will have IHM systems capable of transmitting vehicle/payload condition ahead to the destination spaceport's SCF. Likewise, passengers and crew, if any, will each be monitored by a personal health monitoring system to report condition and any potential medical problems or emergencies. Any potential problems would be identified by AI analysis and reported to the recovery operation for appropriate action upon vehicle/payload arrival/landing. Horizontal landing facilities will be equipped with precision guidance and landing systems and will be all-weather capable. The overall spaceport will have active local area tracking and environmental monitoring (weather) systems for the spaceport area as well as all landing areas. Additionally, runways will have automated FOD detection and removal capability. Upon landing, horizontally operating vehicles will taxi under their own power or be towed via a SCF / PLPS-controlled robotic tug or facility-integral tow device from the landing facility to a dedicated recovery location. Vertically landing vehicles and components not equipped for surface towing, will be captured by a CCF / PLPS-controlled robotic transporter with automated, standardized interfaces and vehicle-to-transport connections for transport to the recovery location.

Those returns culminating in water landings will be accomplished at spaceports geographically capable of providing required facilities and will be tracked and monitored as with other operations described previously herein. Recovery activities will be initiated from supporting spaceport port infrastructure by the SCF with recovery vessels and infrastructure positioned for vehicle/payload capture immediately upon touchdown, if the landing vehicle is not capable of transporting itself to spaceport wharf facilities for transfer to land. As with other recoveries, it is anticipated IHM systems will convey status and condition data to the SCF, which will direct safing and recovery operations accordingly. Recovery infrastructure will be automated to the greatest extent possible with programmable, reconfigurable interfaces to serve multiple vehicle types and programs. Upon recovery, flight elements and payloads will be transported to land-based spaceport facilities for further processing as described for other vehicle types.

Many vehicles will be self-safing and self-inerting with sensors reporting to the SCF any potentially hazardous conditions. Standardized ground service equipment and fittings will expedite the safing process. Vehicles not so equipped will pass through a scanner to detect any potentially hazardous conditions with data transmitted wirelessly to the SCF for AI analysis with immediate clearance or operator notification if a problem is detected. The scanner will also receive vehicle and payload condition and servicing data from on-board IHM systems. The data will be transmitted wirelessly to the SCF for analysis. This will facilitate proactive automated scheduling of service and maintenance procedures necessary to prepare vehicles and payload containers for rapid return to service. Additionally, scanned payload data will facilitate scheduling and handling of down payloads through common payload processing operations and analysis of payload condition via the AI database to enable scheduling of required repairs and service, when necessary, and direct access to payload data by payload customers.

Once the vehicle is verified safe, passengers and crew (if any) exit the vehicle. For most spaceport recoveries, passengers and crew will exit the vehicle to automated loading bridges leading to passenger/crew support operations or enter automated transporters if support operations are located remote from the recovery position. Vehicles landing away from the spaceport on land or water will be recovered by special handling and transport equipment. It is anticipated passengers will exit the vehicle to transporters for return to the spaceport as soon as the vehicle is recovered to a secure position. Thereafter, vehicles are towed via in-pavement automated tow or robotic tug system to the arriving vehicle/payload processing operations. For international arrivals, international and customs facilities will be available at the spaceport for passengers and vehicles with cargo/payloads.

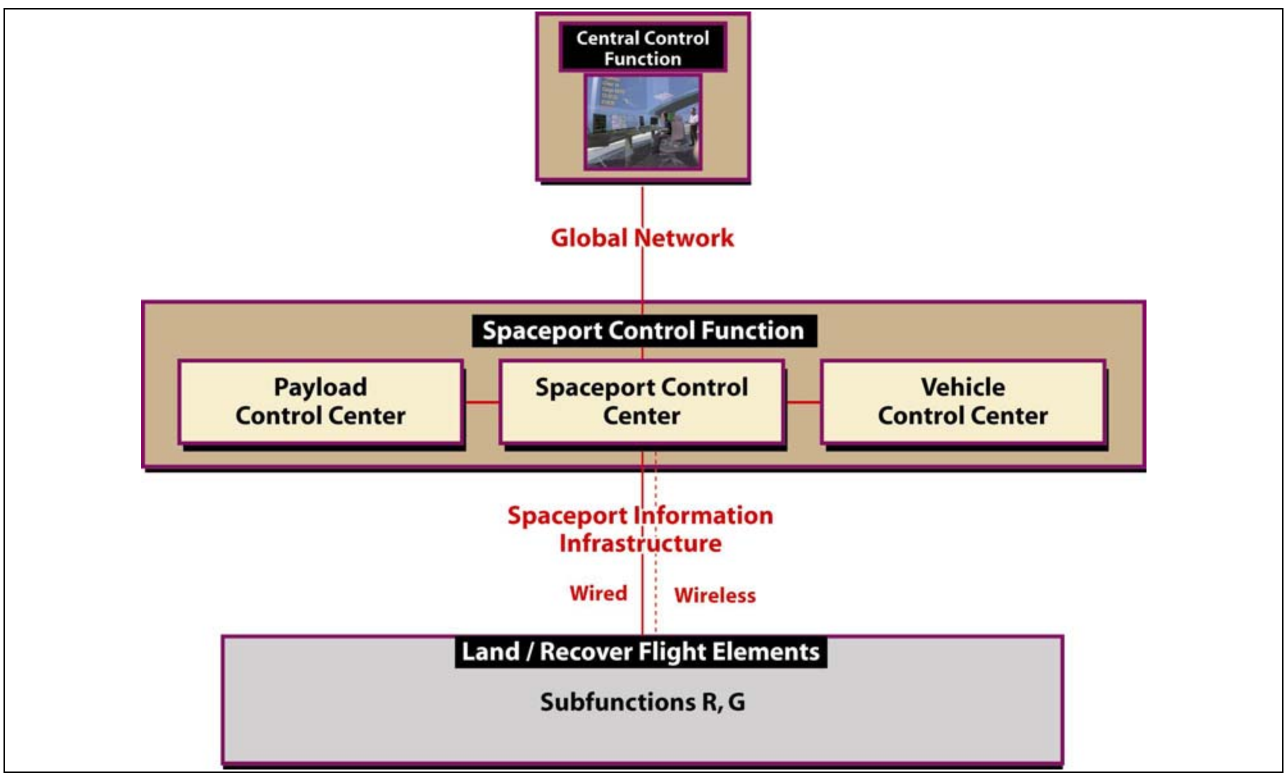


Figure 4-11 Landing & Recovery Operations Relationship Diagram

4.3 PAYLOAD ELEMENT OPERATIONS

Payload element operations are all activities associated with receiving, staging, assembling and preparing up-payloads for integration with the launch/flight vehicle and intake of down-payloads and payload infrastructure returned from space and the subsequent disassembly, staging and shipping of payloads and components. The envisioned spaceport architecture includes common payload processing operations serving most programs and vehicle types. It is assumed military munitions payloads will be handled, stored, processed and integrated through separate operations to maintain appropriate safety separations from other program operations.

Receive and Accept Payload Elements, Assemble Payload Elements, Service and Checkout Payload Elements and Restore Payload Elements

A central payload processing operation is envisioned to accommodate all pre flight (up) and post flight (down) activities through which most payloads would be processed. Up payloads are received, accepted, assembled and undergo final checkout operations in one common operation serving most vehicle types and mission configurations. It is envisioned payloads, containers and related equipment would be received, accepted and tracked through one location. Most payloads would remain at the same location for assembly, containerization (if not already containerized), and checkout. Exceptions could include fully assembled and specialized payloads transferred directly to program payload or integration operations and munitions payloads, which would be tracked through the central payload inventory control system but be received and scanned at separate, remotely located, munitions storage, processing and integration operations. With the introduction of evolved vehicles, especially in the second era, the number and types of payloads may be expected to increase significantly. Horizontally operating vehicles with modular payload containers and payload bay inserts will carry a variety of payloads to orbit or near orbit, including ISR satellite and surveillance equipment, on orbit servicing modules and satellite retrieval equipment, munitions delivery systems, scientific laboratories, manufacturing modules, probes and space craft of all descriptions and purposes. Arrangement of operations should allow secure separation of payload processing areas when required by specific mission activities.

The implementation of common processing facilities with specialized processing areas, automated payload assembly and interface systems, and container to payload integration and testing equipment could offer many opportunities for application of enabling technologies. Payload receiving and processing operations would be configured to accommodate payloads arriving at the spaceport in various stages of launch readiness, from payloads requiring assembly to those fully integrated, tested, and containerized off-site. The receiving and acceptance function would include scanning capability to verify payload condition and identify any infractions or potential operational / servicing problems prior to acceptance. Wireless scan and check-in equipment interfaced with the SCF will be used to facilitate the remote check-in of payloads containerized at off-spaceport locations. It is envisioned all payloads arriving at the spaceport, including those processed off-site, will contain RFID-encoded chip information for identification. All movements to and through the spaceport would be tracked by the SCF, enabled globally by GPS and then within the spaceport by the spaceport Precision Local Positioning System (PLPS). Encoded payload documentation received with the payload and scanned into the SCF database at check-in would provide all necessary information regarding payload handling procedures, servicing requirements, specifications, trouble-shooting and other pertinent information. This information becomes part of the SCF database, which applies an Artificial Intelligence (AI) analysis of previously stored operational and service information to recognize problems and recommend solutions based on past performance. If a potential problem is detected, the SCF will interact with the payload/container to remedy the anomaly, or if necessary, notify the operator and identify the appropriate remedy procedure. Payload status data maintained by the SCF is also accessible in real time to the payload customer. This information will supplement the diagnostics services database to inform operators of the most safe and efficient ways to handle each payload.

Movement and handling of payloads and containers within the facility may be accomplished via PLPS-controlled pallets or robotic transporters directed by the SCF. Integration of payloads into containers, when required, could be accomplished via robotic handling equipment with PLPS-referenced SCF-controlled automatic interfaces and alignment systems. It is envisioned spaceports will maintain infrastructure to support handling and payload integration for several standardized modular container "classes" capable of accommodating various payload types. Payload-to-container service interfaces will facilitate automated seals, standardized ports, and self-healing QDs. Staging and storage/holding of containerized payloads could be accomplished via an automated warehouse and retrieval system utilizing the palletized transport system controlled by the SCF for just-on-time retrieval and delivery of payloads to the appropriate vehicle/payload integration location, based on processing and launch schedules managed in the SCF.

Once containerized, payloads would not require service from the outside. Internal servicing and monitoring interfaces within the container would include power, data, fluids, thermal, structural payload-to-container attachment and wireless communications. External container-to-vehicle interfaces for the container include wireless communications and standardized structural attachment. Both payload and container would have Integrated Health Monitoring (IHM) systems with wireless external interfaces facilitating continual payload status monitoring via the SCF-based external diagnostics system. Advanced Personal IT Platforms (PIPs) with hands-free operation provide an interface to the SCF and allow remote payload condition check and verification at completion of containerization, throughout the staging period and any time up to launch. This function also provides system users access to prescriptive care plans as part of the SCF available to spaceport customers.

At the completion of checkout operations the assembled and integrated payloads would be transferred to the staging/holding area or transported directly to the program integration operations location (or to the designated launch site if integration is to occur at the pad).

In addition to processing up payloads, it is anticipated the common payload operation will process most down payloads and modular payload containers returned from orbit. The introduction of reusable launch vehicles that can perform a variety of on-orbit service and retrieval activities is expected to result in a significant increase in the volume of down payloads returning to spaceports in the future. Operations envisioned would include down payload extraction operations, down payload processing, and a down payload container restoration area for the refurbishment and maintenance of payload containers and handling equipment. The operation would be automated with SCF-controlled preset interfaces for extraction, handling and restoration activities. Container and container-to-payload IHM systems are checked and any anomalies identified by AI analysis are resolved. Restored containers would be forwarded to a container staging/holding area until being transferred to the payload integration area. Extracted down payloads would be transferred to dedicated down payload decontamination, processing, handling and shipping operations as provided and described herein for up payloads.

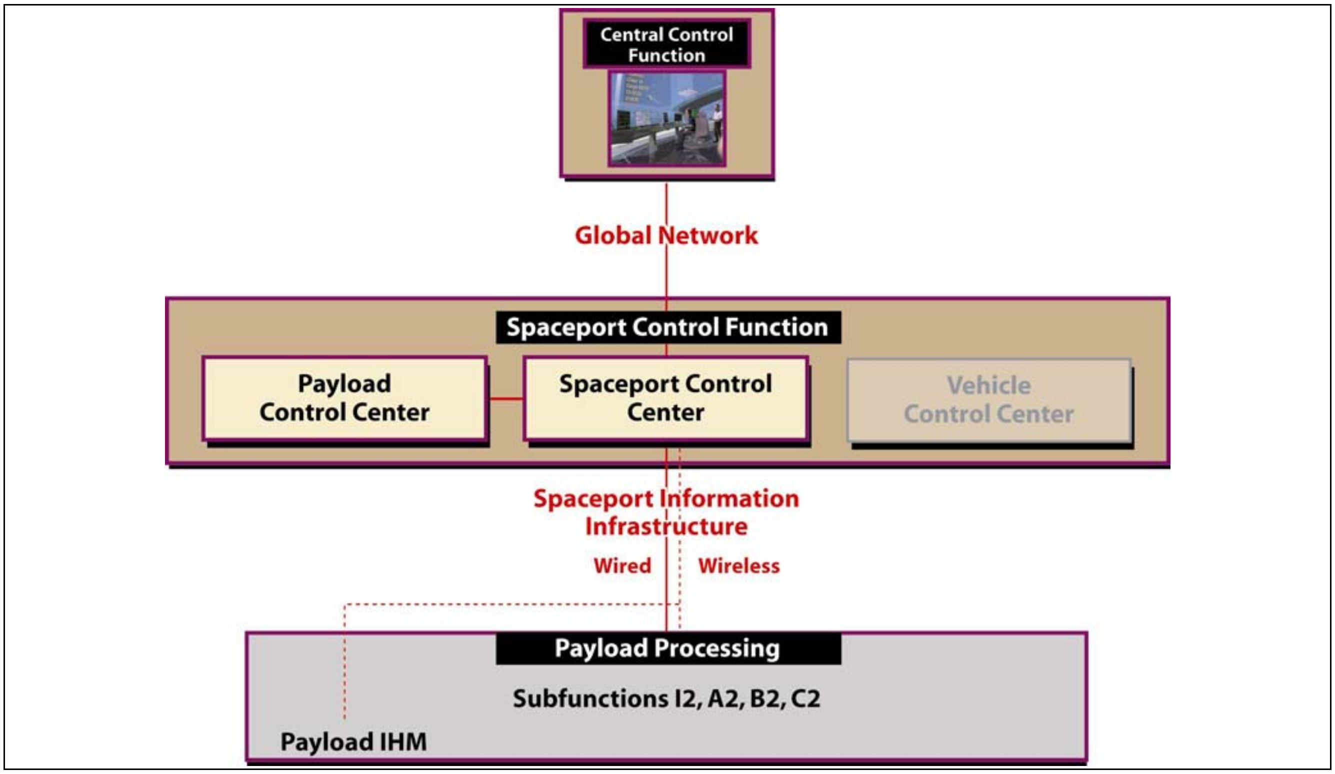


Figure 4-12 Payload Processing Relationship Diagram

4.4 Flight and Ground Traffic Control and Safety Operations

Ground Traffic Control and Safety functions are those necessary to ensure safe ground movement within the spaceport and protect the public and spaceport assets. The spaceport will mandate procedures, operations and equipment necessary to maintain safe and efficient operations.

Flight and Ground Traffic Control and Safety Operations

Ground traffic control and safety is coordinated by the SCF and pertains to all movements of ground service equipment, payloads and flight elements within the spaceport. It is assumed all controlled elements will be equipped with tracking sensors and element-specific encoding to facilitate tracking and identification by the Precision Localized Positioning System (PLPS). Based on the overall spaceport operations schedule, the SCF will direct the timing and routing of all automated transport systems and autonomously moving elements within the spaceport. The system will also include the ability to scan for and remove Foreign Objects and Debris (FOD) on all transportation routs within the spaceport. It is envisioned tugs, transporters and vehicles capable of autonomous movement will be equipped with scanners to detect FOD. Detection of material would automatically activate the SCF-controlled removal system, identify the detected item and implement the appropriate removal system, which might include water jets or laser devices integral to the pavement or automated PLPS-guided FOD removal drones.

4.5 Enabling Operations

Enabling operations are management, operational, facility and maintenance activities related to the overall spaceport infrastructure that supports all activities at a spaceport.

Spaceport Logistics and Management of Spaceport and Flight System Operations

The spaceport logistics activity controls the flow of all consumable materials, parts and supplies and administers all training and certification activities within the spaceport. The SCF is integral to the scheduling and control of most spaceport activities and will draw on that base of information to effect materials and commodities flow to supply scheduled spaceport activities. Many spaceport facilities, infrastructure elements and most flight elements and payloads will have IHM systems reporting to the SCF for condition evaluation and service/maintenance procedures. The SCF will automatically order and maintain inventories of required parts and supplies and initiate supply movements via automated delivery systems to meet scheduled activities and events. Materials and supplies not subject to automatic ordering will be requisitioned to the SCF for automated acquisition and delivery. The SCF will also maintain a materials acquisition database of specifications, bidding procedures, qualified bidders, and history of anticipated reasonable cost for all required parts, equipment and supplies and will initiate a competitive bidding process when possible to ensure the spaceport receives needed supplies and materials at a cost that is reasonable and within the operating budget. It is also envisioned the SCF will control the procurement, receipt, distribution, and as applicable, production of propellants and gasses necessary to meet scheduled launch demand.

It is envisioned the SCF will control the parts and component inventory for most programs and flight vehicle operations, placing orders, recording receipt and initiating distribution and maintaining an inventory of parts and supplies throughout the spaceport in support of all programs and service/maintenance activities. Parts, components and supplies arriving at the spaceport will contain encoded chips similar to flight element identifiers, and will be scanned upon delivery to the common receiving operation. Scanned data is wirelessly transmitted to the SCF providing all pertinent information including identifying part numbers, related program, order origination (specific application or general inventory) and when appropriate, manufacturer information, specifications, and service and installation information. Parts and supplies not immediately utilized are entered into inventory and forwarded to an automated warehouse facility for storage and future retrieval.

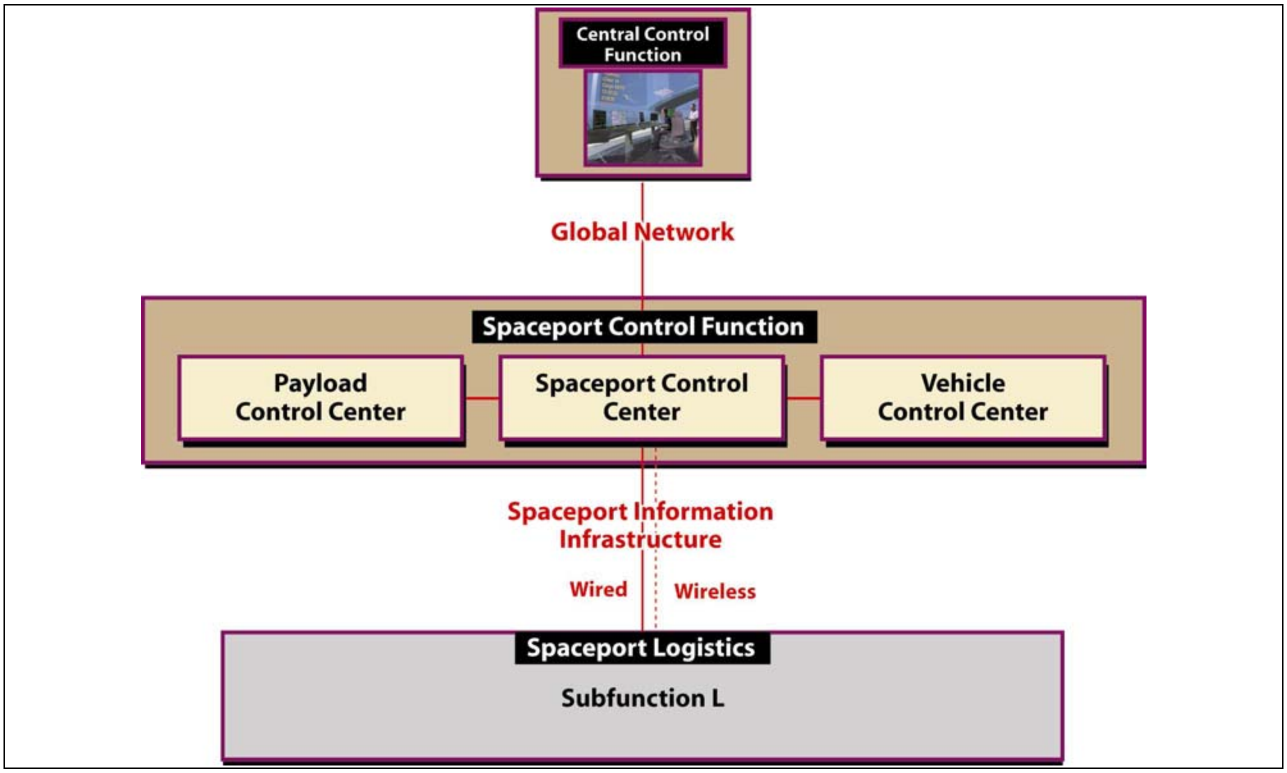


Figure 4-13 Spaceport Logistics Relationship Diagram

Spaceport-Provided Support Services

Spaceport provided support services include all infrastructure, utilities, facilities and facilities maintenance, and support services not directly assigned to a mission or operational program.

Infrastructure includes the construction and maintenance of all surface improvements including roadways, parking areas, walkways, drainage systems and landscaping, surface transportation systems, runways and shared operational areas necessary to support spaceport operations and mission requirements. Utilities include facilities and distribution systems (and maintenance thereof) required for distribution (and potentially generation or co/poly-generation) of all utilities and commodities required to operate the spaceport, including (but not necessarily limited to) power, telecommunications and data transmission, water and sewer, telemetry and tracking systems, and fuels and gasses. It is envisioned the SCF will monitor operation and utilization of all utilities and many infrastructure components, identifying potential operational problems and scheduling routine and preventative maintenance. To the extent the application of technological advances is cost effective, improved materials, remote sensing, self-healing and self-sealing systems developed for program systems could also have applications for infrastructure systems.

Facilities include all structures and above ground improvements not considered infrastructure and not belonging to a specific program. The spaceport provides for the construction and ongoing maintenance of all facilities and improvements necessary for the operation of the spaceport in support of mission operational activities. It is anticipated the SCF will interface with building automation systems to manage system operations and facilitate operational efficiency.

The SCF will also keep maintenance records for all facilities and schedule routine and preventative maintenance activities based on AI analysis of historical facility systems and materials data to optimize facility maintenance while minimizing lifecycle maintenance costs. To the extent the application of technological advances is cost effective, improved materials, remote sensing, self-healing and self-sealing systems developed for flight vehicle and payload systems could also have applications for buildings and above ground improvements.

The spaceport will also provide support services required for the operation of the spaceport and in support of spaceport mission programs. Support services include, but are not necessarily limited to spaceport rescue and fire fighting and security, which includes perimeter security facilities and barriers, facility protection systems for surveillance and detection, and security force personnel and supporting facilities and equipment. It is assumed the SCF will monitor and be interfaced with emergency services notification systems and will implement emergency services procedures as part of operational activities when an emergency is identified. It is also assumed the SCF will interface with all spaceport security and monitoring systems and outside security and governmental agencies to coordinate security activities and proactively identify potential security concerns.

Offline Maintenance, Repair and Overhaul

The offline maintenance, repair and overhaul (OMRO) function provides for heavy maintenance, overhaul, and modifications of flight elements when it is necessary to remove an element from service for an extended period of time. OMRO also provides for heavy maintenance and repair of Ground Service Equipment (GSE) and general maintenance and repair of all spaceport operations, maintenance and service vehicles, equipment and infrastructure. It is envisioned eventually most flight elements and much of the spaceport operating infrastructure and equipment will be continually monitored by IHM systems wirelessly transmitting condition and operational status to the SCF. By applying its AI analysis to the database of vehicle and equipment specifications and maintenance schedules, the SCF will anticipate and identify emerging conditions requiring overhaul, as well as scheduled heavy maintenance and overhaul procedures and those necessary based on extent of utilization and historical performance and failure records. The SCF will automatically schedule the required work, reserve a service position at the OMRO operation, and requisition/verify availability/order all required supplies and repair parts/replacement modules. At the scheduled time, the SCF will initiate transfer of the subject vehicle or equipment to the OMRO and activate service interface configurations to the appropriate vehicle/equipment specifications. Any required parts/modules and supplies will be automatically transferred from inventory to the repair location.

It is envisioned the OMRO operation will be automated to the greatest extent possible with many maintenance and overhaul operations accomplished by automated, robotic activities controlled by the SCF. Operations requiring human interface will be assisted by AI support utilizing remote sensors, problem solving analysis, heads-up displays, and PIPs providing access to service schematics, specifications, service history and recommended repair procedures. Vehicles arrive at the OMRO operation under their own power, or on automated tugs or transporters, directed by the SCF and guided by the PLPS system. Automated lifting and positioning interface equipment, preset by the SCF, engage the element and facilitate service access. When repairs are completed, the SCF reviews data received from the IHM, or operational test equipment if IHM is not in use, to verify successful completion of the work and certification of readiness to return to operational status.

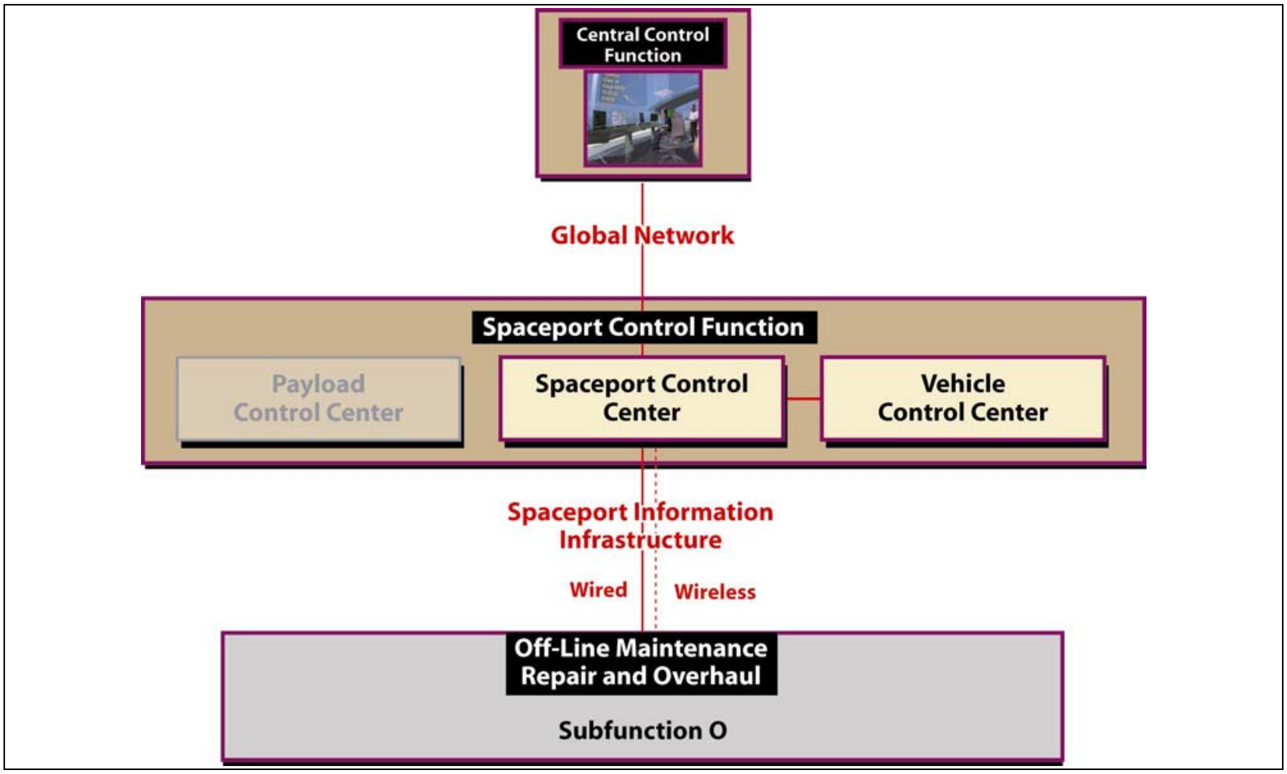


Figure 4-14 Off-Line Maintenance, Repair and Overhaul Relationship Diagram

Public and Community Support Services

Public and community support services will be characterized by community outreach and economic development, strategic facility and community planning, and transportation planning. The spaceport will reach out to surrounding communities and the general public through an established program of public and community support services to establish and maintain positive interaction with the public and surrounding communities and provide information related to spaceport and mission activities. It should also work in partnership with surrounding communities to encourage interaction through businesses development, community services and educational programs. The spaceport should be proactive in addressing environmental preservation and should have a plan for future growth and development mutually responsive to spaceport and community needs and concerns. The spaceport may develop and encourage on-site community interaction through launch viewing and information and visitor centers featuring historical artifacts, current mission activities and evolutionary technologies.

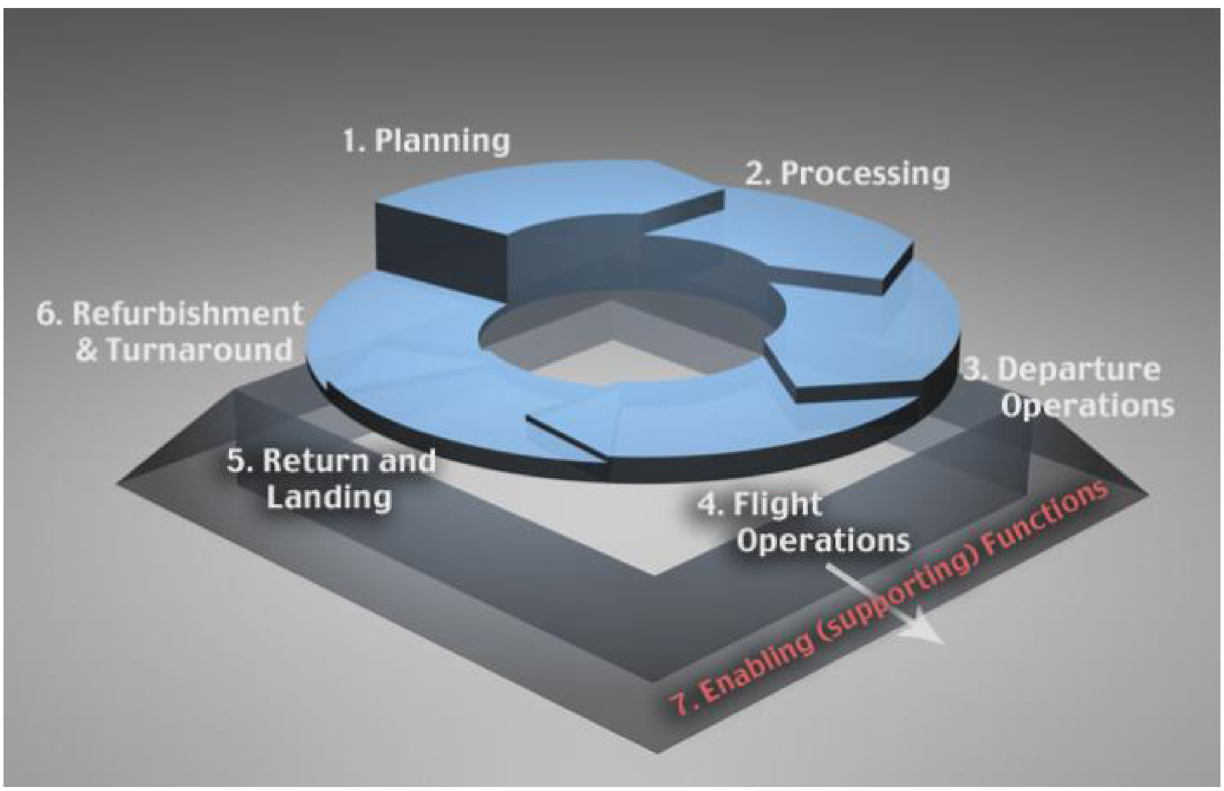
For a more detailed description of conceptual spaceport architectures please see Appendix 5 of this document.

5.0 FUTURE SPACEPORT OPERATIONS

While the previous section described the elements and functions of future spaceports, this section describes development of spaceport operational models to accommodate all identified design reference missions.

5.1 SPACEPORT OPERATIONS LIFE CYCLE

The Spaceport Operations Life Cycle consists of six sequential operational phases associated with space launch and flight test missions, supported by Enabling Functions (**See Figure 5-1**). To support these missions, spaceports must be configured to provide required services and infrastructure to accommodate activities within each phase.



6 sequential phases of space launch and flight test missions

Source: FIRST Space Launch and Test Range CONOPS

Figure 5-1 Spaceport Operations Life Cycle

To fully define spaceport operational requirements, spaceport functions are presented below corresponding with the six sequential phases of the Spaceport Operations Life Cycle.

1. **Planning**

- K Traffic Control and Safety
- L Spaceport Logistics
- M Management of Spaceport and Flight System Operations
- N Spaceport-Provided Support Services
- P Public and Community Support Services

2. **Processing**
   - A1 Receive and Accept Flight Elements
   - A2 Receive and Accept Payload Elements
   - B1 Assemble Flight Elements
   - B2 Assemble Payload Elements
   - C1 Service and Checkout Flight Elements
   - C2 Service and Checkout Payload Elements
   - D Integrate Flight System and Payload

3. **Departure Operations**
   - E Execute Departure Operations

4. **Flight Operations**
   - F Monitor and Manage the Flight

5. **Return and Landing**
   - G Land/Recover Flight Elements and Payload

6. **Refurbishment and Turnaround**
   - H1 Prepare Flight Elements for Turnaround
   - H2 Prepare Payload Elements for Turnaround
   - I1 Restore Flight Elements
   - I2 Restore Payload Elements
   - J Restore Ground Systems for Reuse
   - O Offline Maintenance, Repair and Overhaul

5.2 Operational Flow Models

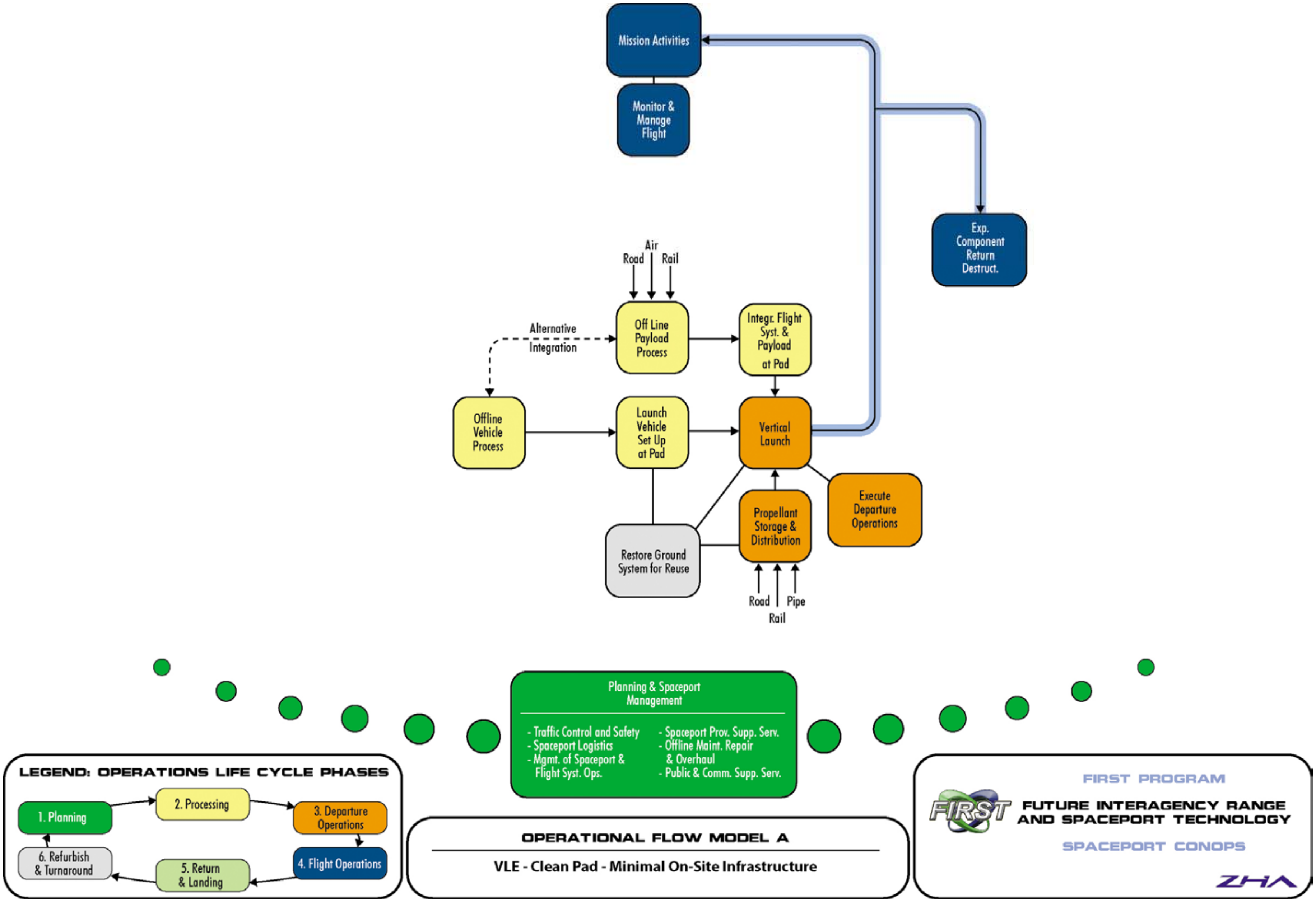
From the list of reference mission configurations and descriptions presented in the Operational Requirements Matrix introduced in Section 3, reference missions with similar or identical operational activities and configurations were grouped together. These groups represent the number of different mission operational activity configurations for which spaceport supporting infrastructure would be required to facilitate all reference missions identified by the Operational Requirements Matrix.

Each group of mission configurations was analyzed to identify all required spaceport functions within the context of the Operations Life Cycle (as presented in Figure 5-1 above) to develop a flow diagram, or Operational Flow Model, depicting the sequenced flow of spaceport functional activities required to facilitate the mission operations defined by the group. Fifteen separate Operational Flow Models were developed as a result of the grouping and subsequent analysis of the reference mission configurations. The models show the sequence of activities necessary to accomplish and support the reference missions attributed to each model, and are presented in sequence corresponding to the Operations Life Cycle Phases.

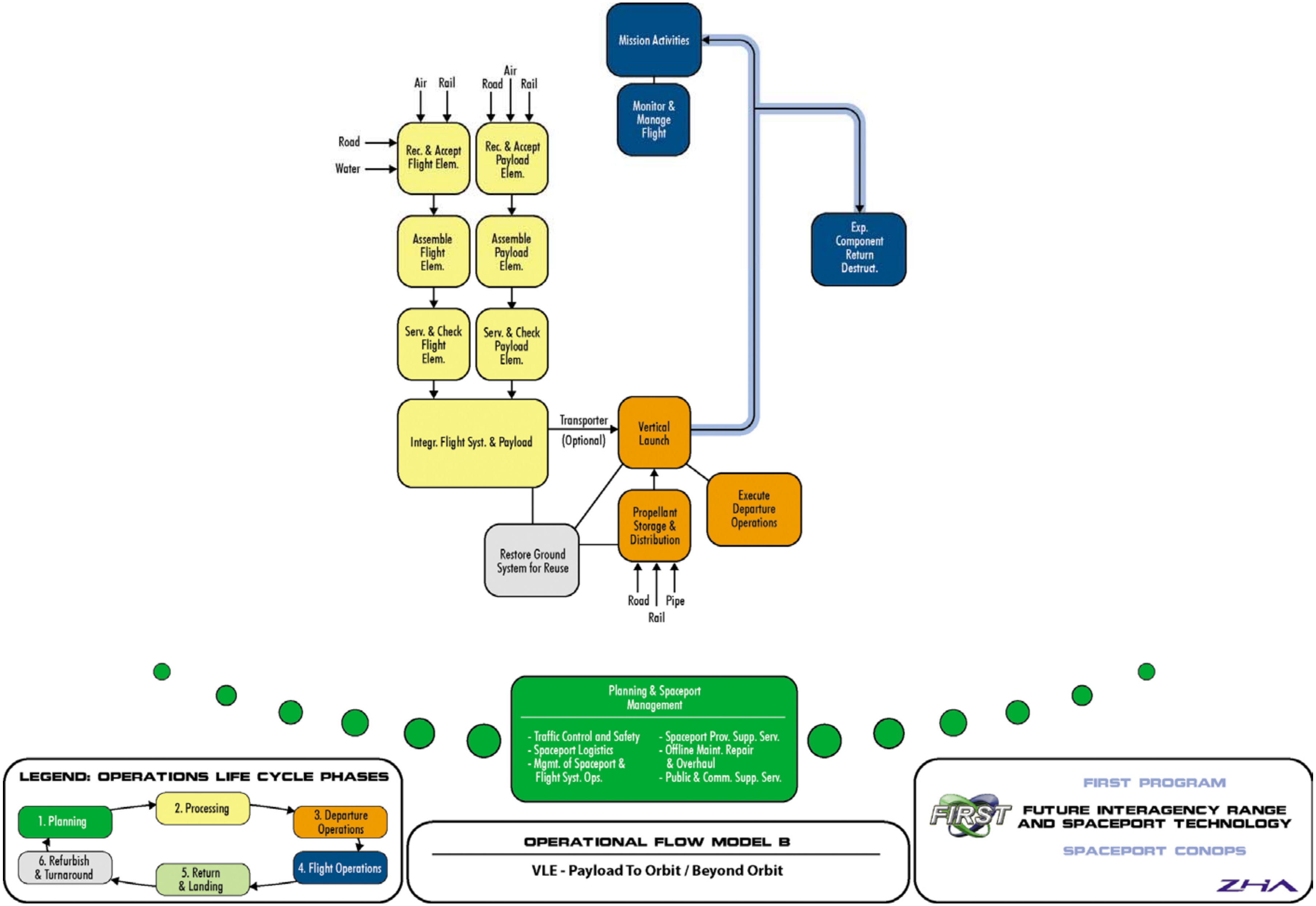
Following are the Operational Flow Models with a brief description of the mission configuration(s) and representative programs related to each. Diagrams of each flow model are included with each description.

<u>Model A – Vertical Launch Expendable (VLE) Clean Pad – Minimal On-Site Infrastructure</u>

Model A accommodates vertical launch expendable vehicles operating from a clean pad requiring minimal launch pad infrastructure and limited assembly and integration facilities at the spaceport. Representative programs include sounding rockets and small vehicle payload-to-orbit.

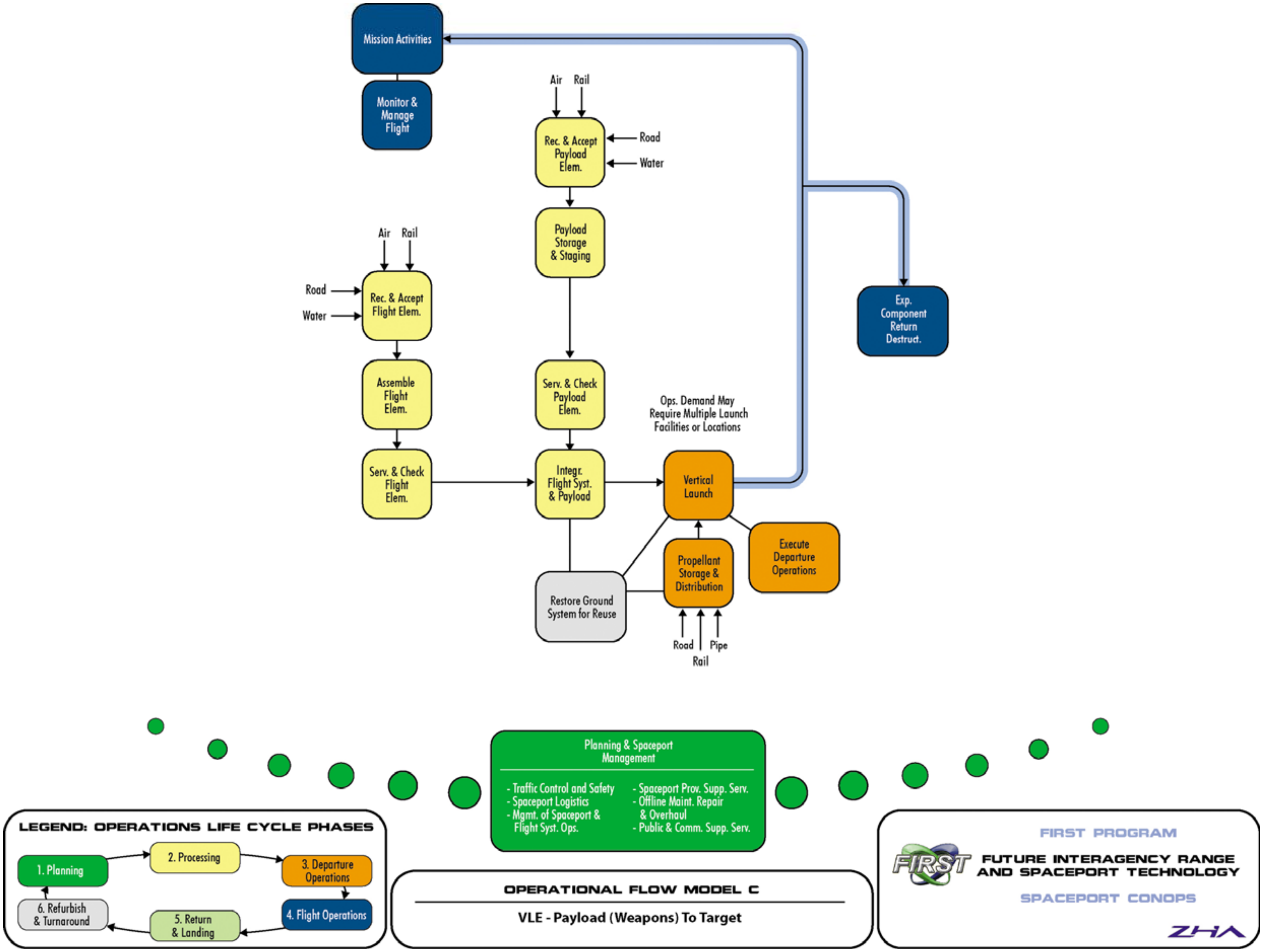


Model B – Vertical Launch Expendable (VLE) Payload to Orbit / Beyond Orbit
Model B accommodates vertical launch expendable vehicles operating from a launch complex requiring supporting launch pad infrastructure and spaceport assembly and integration facilities. Representative programs include a variety of small to heavy launch vehicles delivering payloads to orbit or to deep space destinations (i.e.: satellites, probes and rovers).
Applicable Design Reference Missions (DRMs) include: Routine Satellite Launch, Responsive Microsat Tactical Ops, and ICBM Flight T&E.



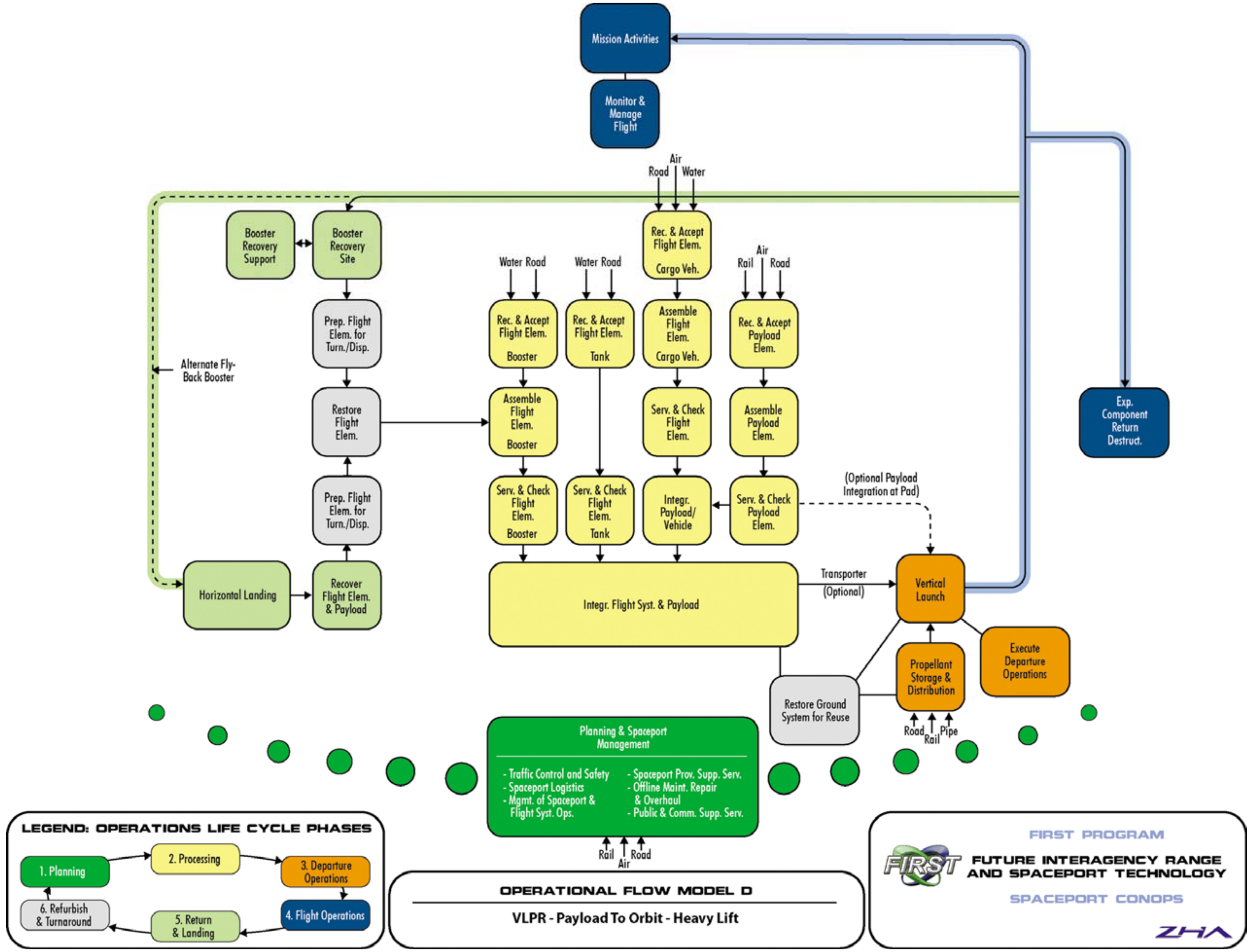
Model C – Vertical Launch Expendable (VLE) Payload (Weapons) to Target

Model C accommodates vertical launch expendable vehicles operating from a launch complex requiring some supporting launch pad infrastructure and spaceport assembly, separate integration facilities and physical separation from other spaceport activities. Specifically relates to DOD delivery of munitions or weapons systems to targets or launch to target intercept. Representative programs include conventional ICBM, ORS-CAV and missile defense systems. **Applicable Design Reference Missions (DRMs) include: Responsive Prompt Global Strike, and Ballistic Missile Defense T&E.**



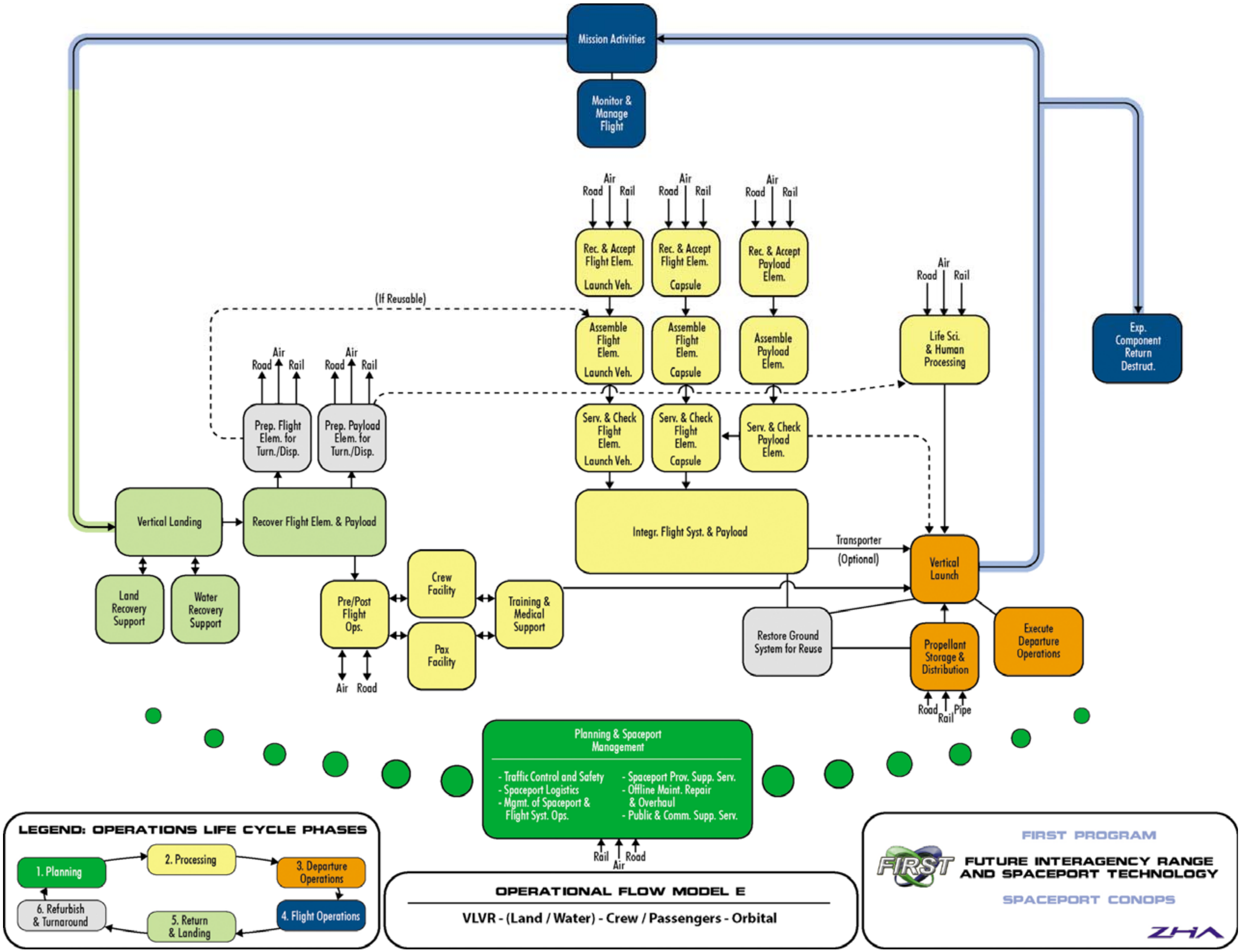
Model D – Vertical Launch Partially Reusable (VLPR) Payload to Orbit – Super Heavy Lift

Model D accommodates vertical launch partially reusable launch of super heavy class payloads to requiring a specialized launch complex with extensive launch pad infrastructure and supporting spaceport infrastructure. Representative program includes side-mount super heavy lift cargo launch vehicle.



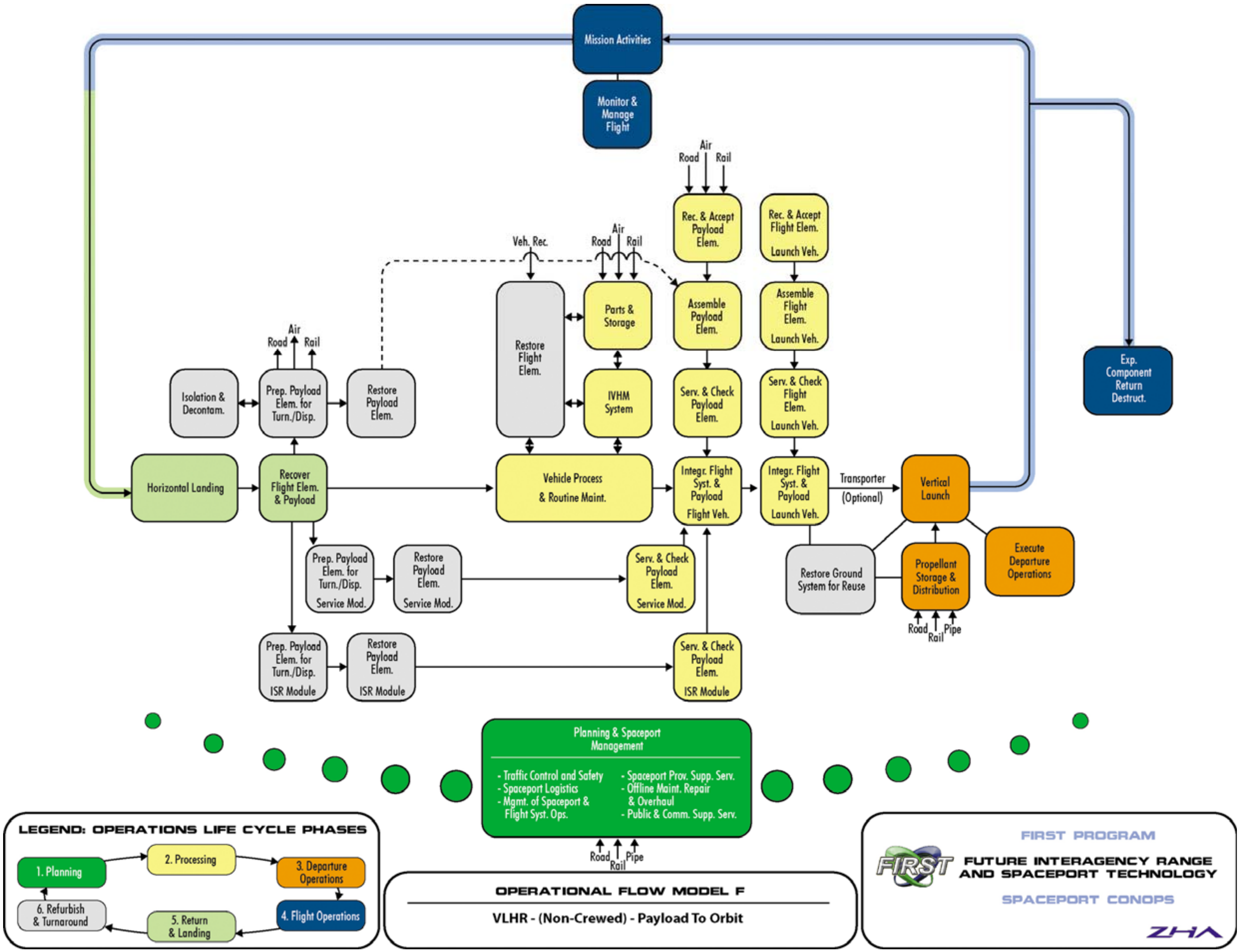
Model E – Vertical launch Vertical Recovery (VLVR) – Crew / Passengers – Orbital

Model E accommodates vertical launch of a vertically recoverable (land or water) crewed flight vehicle (capsule), with option for passengers, operating from a launch pad with infrastructure supporting crewed missions. Representative programs include Soyuz, and potentially capsule versions of OSP or CEV, for example. **Applicable Design Reference Missions (DRMs) include: Routine Lunar Exploration Crewed, and Responsive Crew Rescue Mission.**

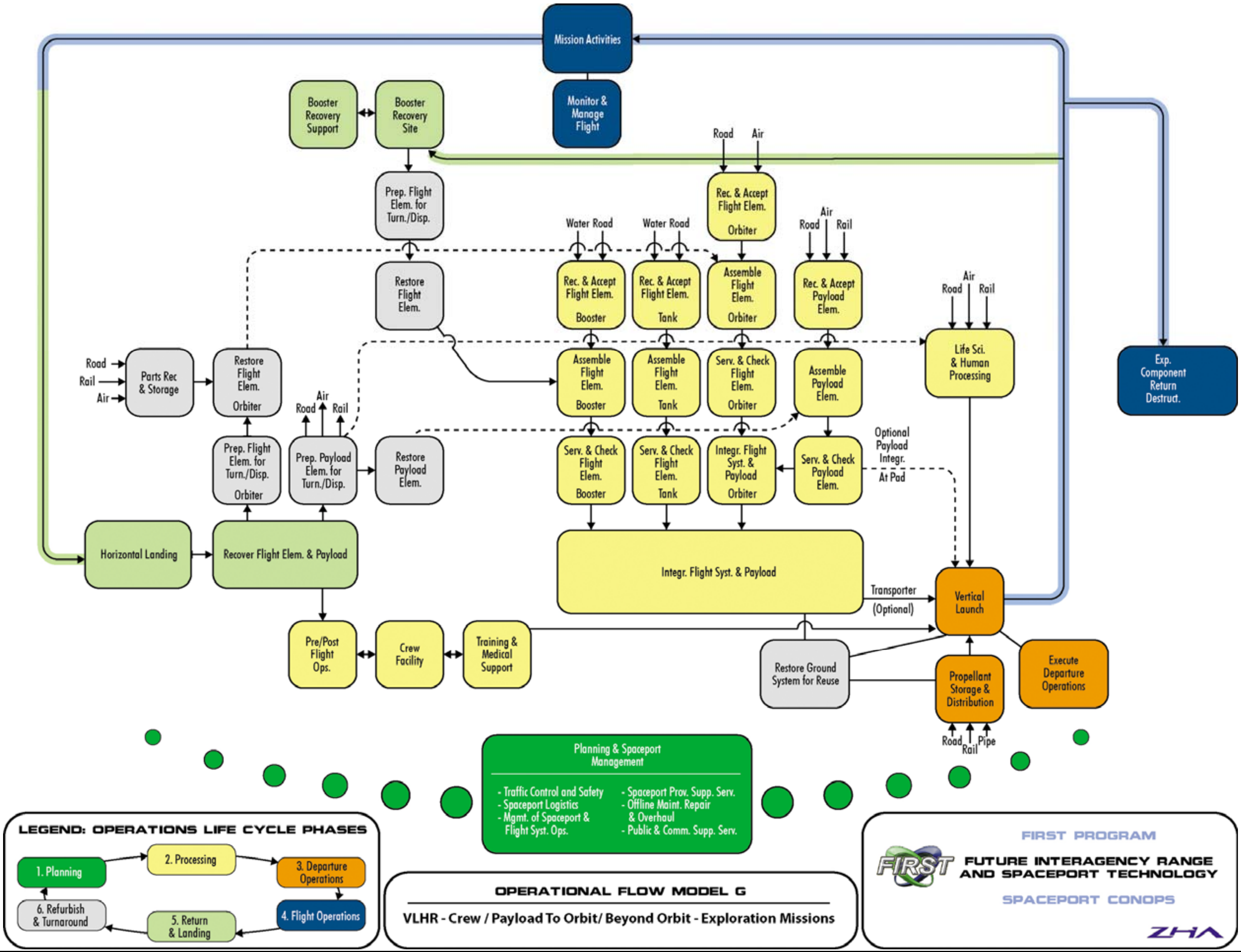


Model F – Vertical launch Horizontal recovery (VLHR) – (Non-Crewed) - Payload to Orbit

Model F accommodates vertical launch of an expendable launch vehicle delivering a reusable flight vehicle with payload (non-munitions) to orbit, requiring launch pad with infrastructure. Flight vehicle delivers payload to orbit and returns to horizontal landing at launch facility. Representative programs include vertical launch version of MSP or HCV-type vehicles for delivery of payloads to orbit, retrieval of payloads from orbit or on-orbit servicing. **Applicable Design Reference Missions (DRMs) include: Responsive Microsat Tactical Ops, and Responsive Commercial Satellite Repair.**

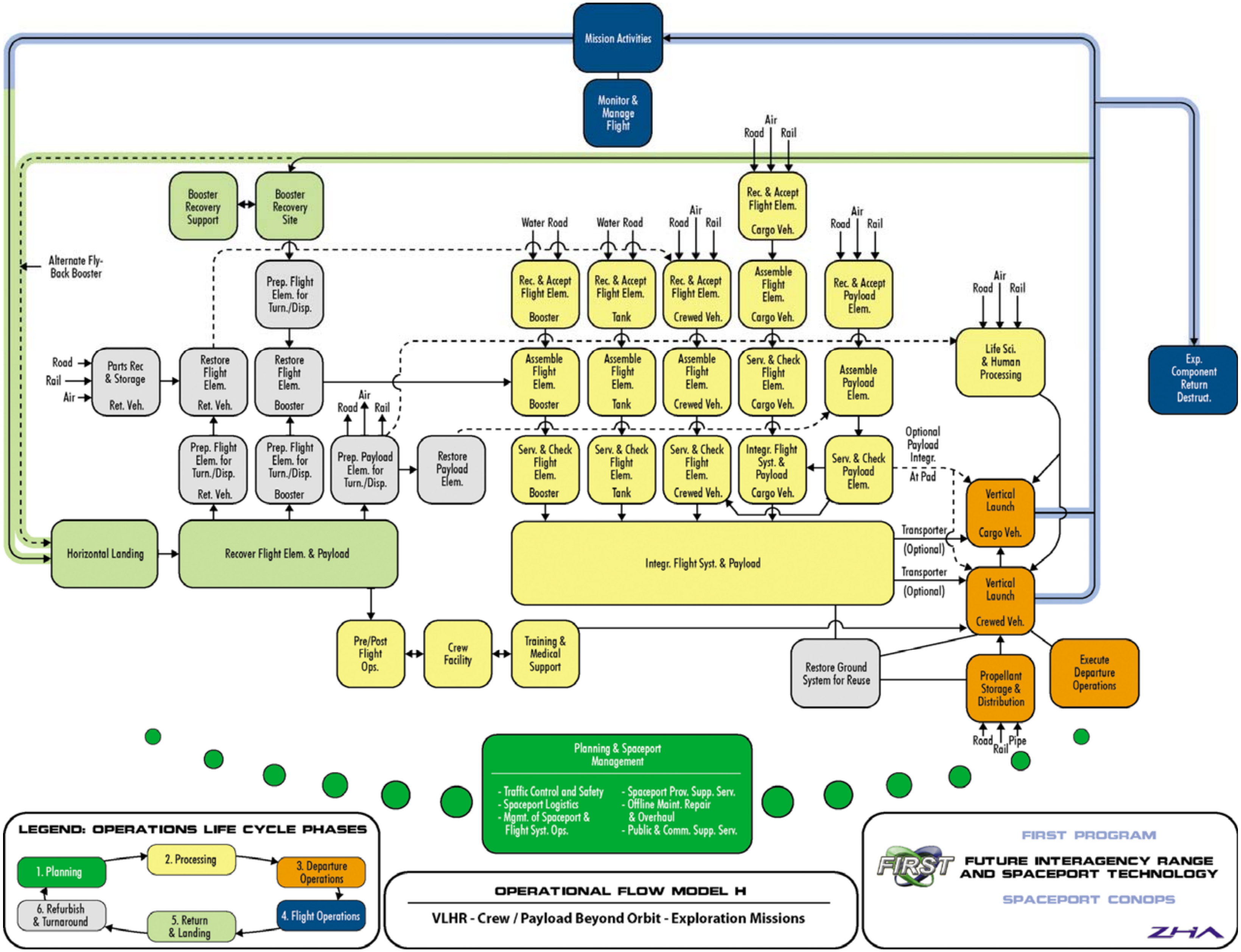


Model G – Vertical Launch Horizontal Recovery – Crew / Payload to Orbit / Beyond Orbit – Exploration Missions
Model G accommodates vertical launch of a crewed reusable vehicle to orbit with return of some reusable components and return of crew vehicle to horizontal landing at launch facility (or optional location). Requires specialized launch complex with extensive launch pad infrastructure and supporting spaceport infrastructure. Representative programs include current Shuttle and potentially CEV and evolved crewed Moon exploration programs. **Applicable Design Reference Missions (DRMs) include: Space Shuttle to / from ISS, Lunar Exploration Crewed, and Crew Rescue Mission.**



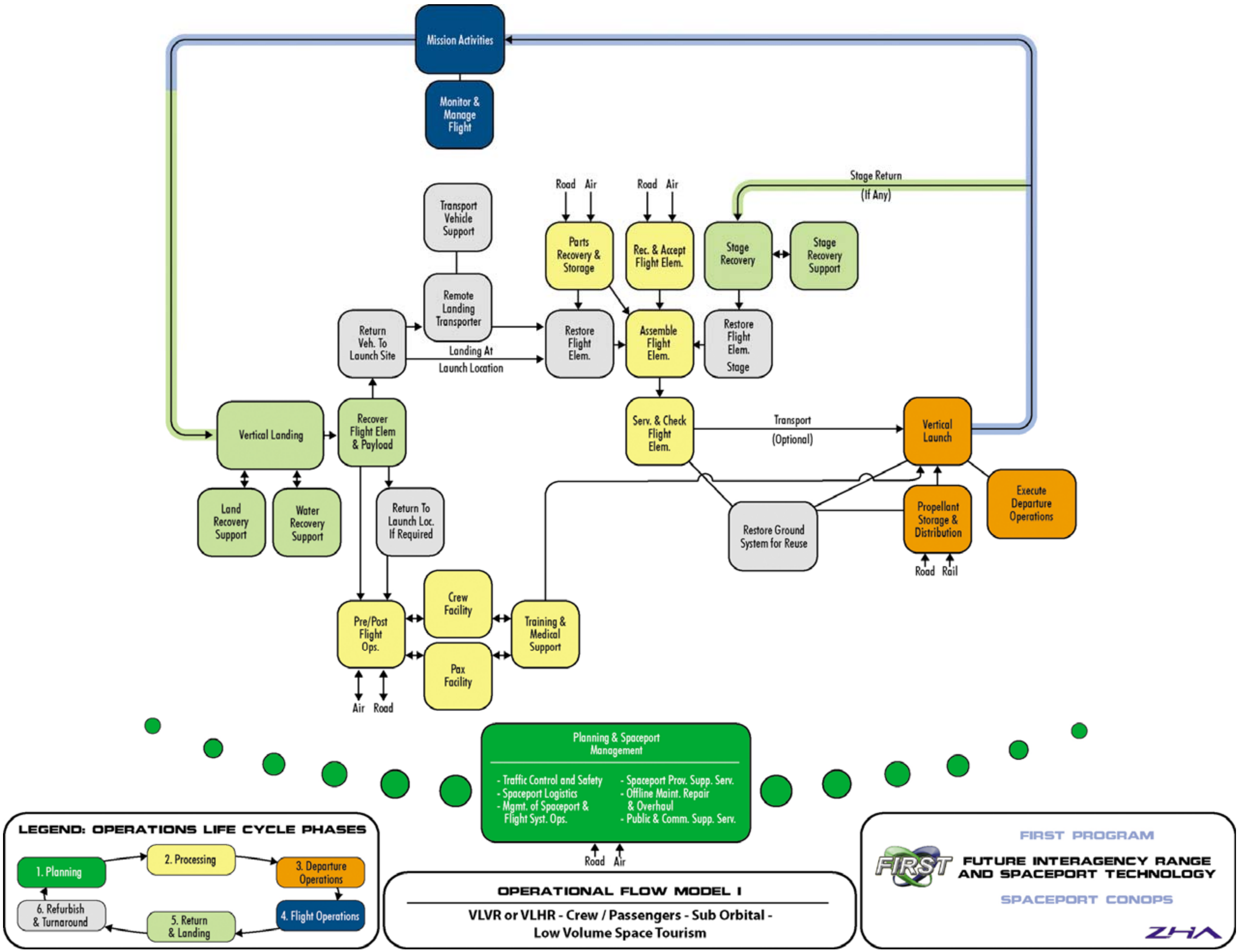
Model H – Vertical Launch Horizontal Recovery – Crew / Payload Beyond Orbit – Exploration Missions

Model H accommodates multiple vertical launches of crewed reusable and cargo-carrying partially reusable vehicles to beyond orbit destinations with return of some reusable components and return of crew vehicle to horizontal landing at launch facility (or optional location). Requires specialized launch complex(es) with extensive launch pad infrastructure and supporting spaceport infrastructure. Representative programs include evolved Mars exploration programs. **Applicable Design Reference Missions (DRMs) include: Mars Exploration Crewed.**

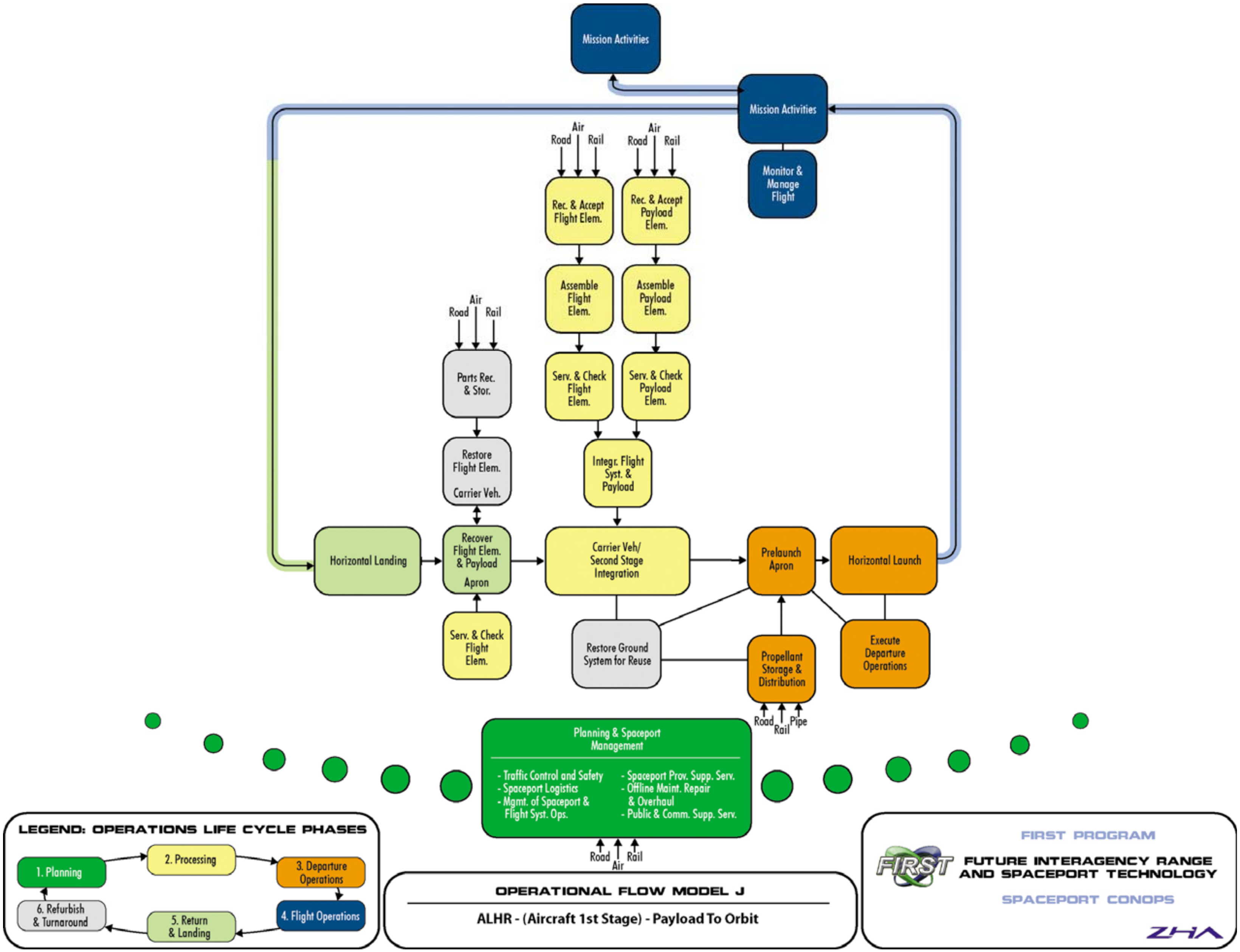


Model I – Vertical Launch Vertical or Horizontal Recovery – Crew / Passengers – Suborbital – Low Volume Space Tourism

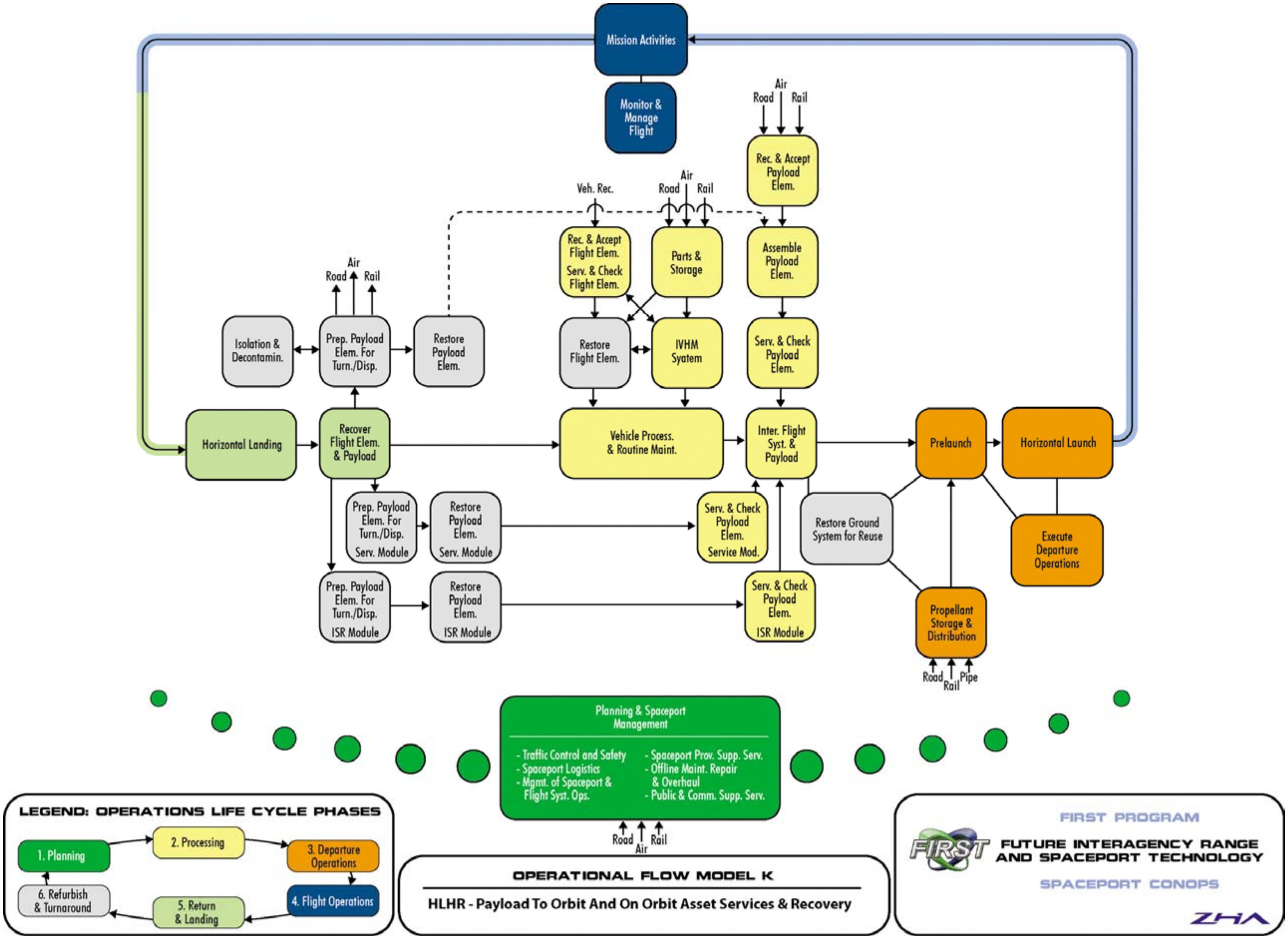
Model I accommodates vertical launch of a reusable launch / flight vehicle carrying crew and passengers on a suborbital trajectory from a launch pad with limited infrastructure. Return of all components to launch site or other location may be either vertical or horizontal. Representative programs include vertically launched X-Prize contenders and related evolving commercial space tourism ventures. **Applicable Design Reference Missions (DRMs) include: Suborbital RLV, and Commercial RLV T&E.**



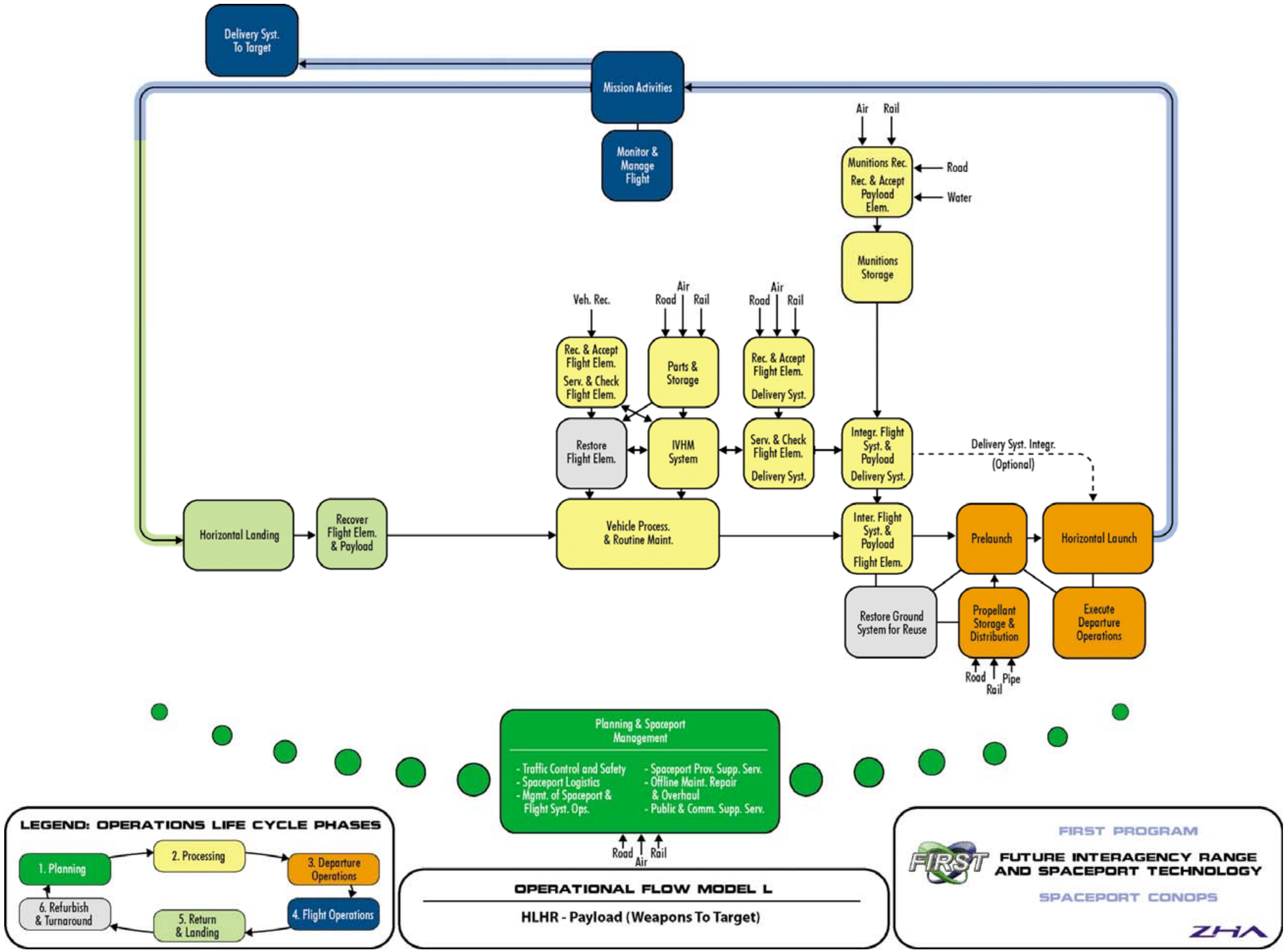
Model J – Air Launch Horizontal Recovery – Aircraft First Stage – Payload to Orbit
Model J accommodates air launch of an expendable second stage to deliver payload to orbit. First stage aircraft operates from a conventional runway and, after air launch, returns to runway at same facility. Representative program is Pegasus. **Applicable Design Reference Missions (DRMs) include: Aeronautical / Hypersonic Flight T&E**



<u>Model K – Horizontal Launch Horizontal Recovery - Payload to Orbit and On-Orbit Asset Services and Recovery</u>
Model K accommodates the horizontal launch of an un-crewed reusable launch vehicle to orbit for payload release (non-munitions) or on-orbit service or asset recovery and return from orbit operations. Vehicle performs reentry and lands at horizontal recovery facility at same location. Representative programs include MSP / HCV-type vehicles performing a variety of operations in the military, civil and commercial sectors. **Applicable Design Reference Missions (DRMs) include: Microsat Tactical Ops, Commercial Satellite Repair, and Aeronautical / Hypersonic Flight T&E,**

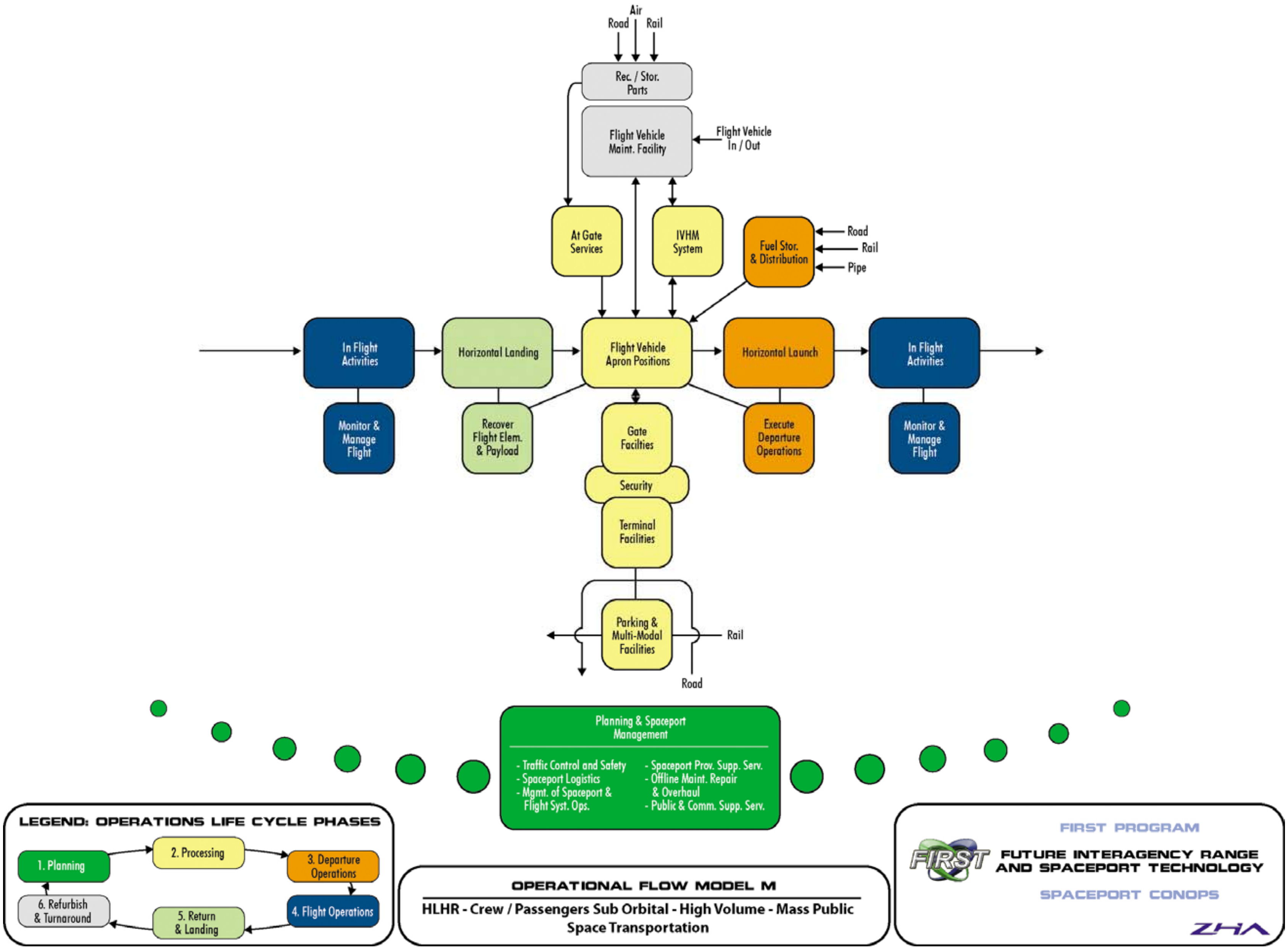


Model L – Horizontal launch Horizontal Recovery – Payload to Target (Weapons)
Model L accommodates the horizontal launch of an un-crewed reusable launch vehicle to orbit or near orbit for release of munitions payload for subsequent delivery to target. Vehicle performs reentry and lands at horizontal recovery facility at same location. Representative programs include MSP / HCV-type vehicles operating under ORS-PGS or DARPA FALCON. **Applicable Design Reference Missions (DRMs) include: Prompt Global Strike.**

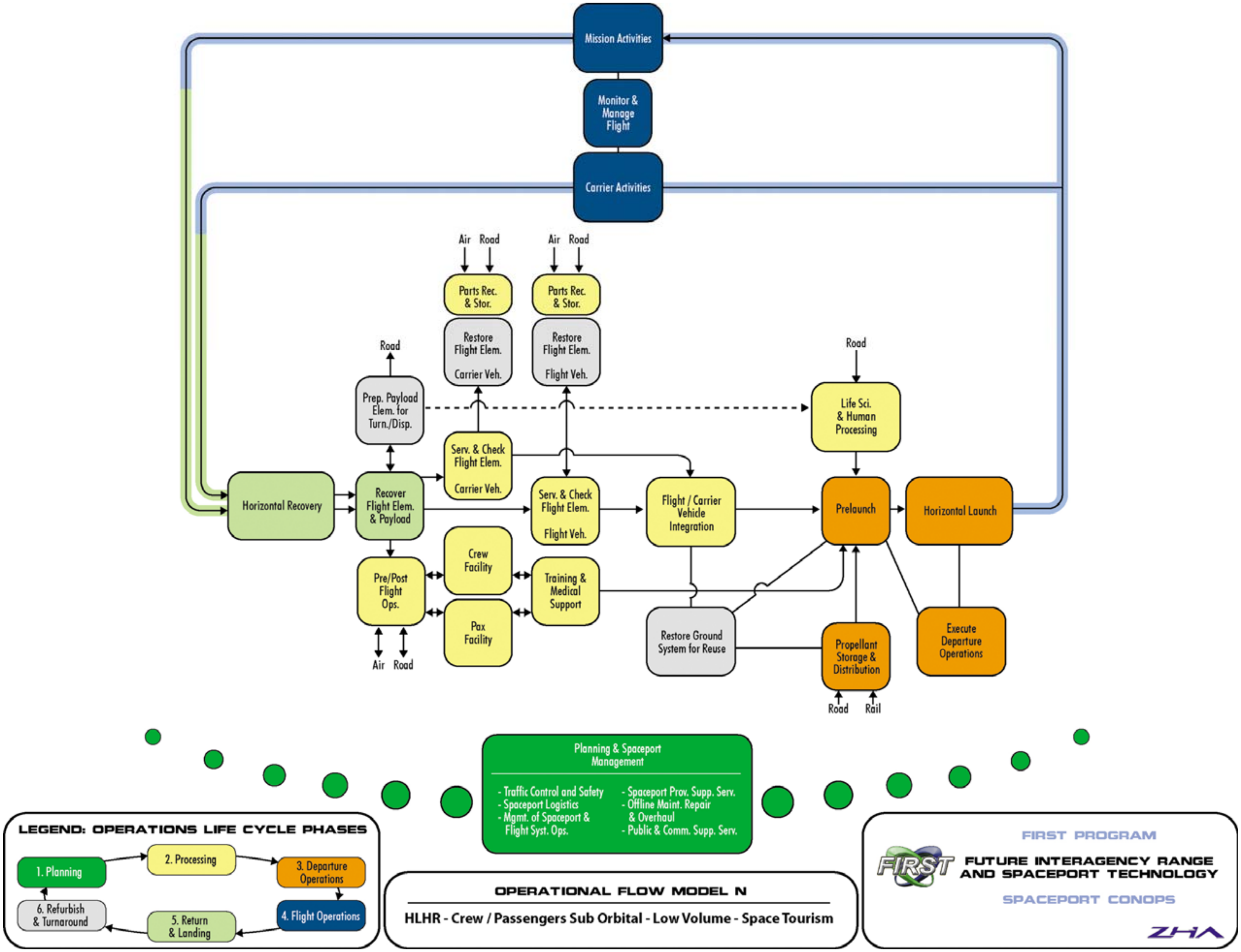


Model M – Horizontal Launch Horizontal Recovery – Crew / Passengers Suborbital – High Volume – Mass Public Space Transportation

Model M accommodates the introduction of evolved hypersonic, suborbital passenger transport flight vehicles into the worldwide airport transportation network. The model assumes hypersonic vehicles will be compatible with the current airport operating environment and will enter the marketplace without requiring significant operational changes at existing airports. Closest representative program is the Concorde aircraft.

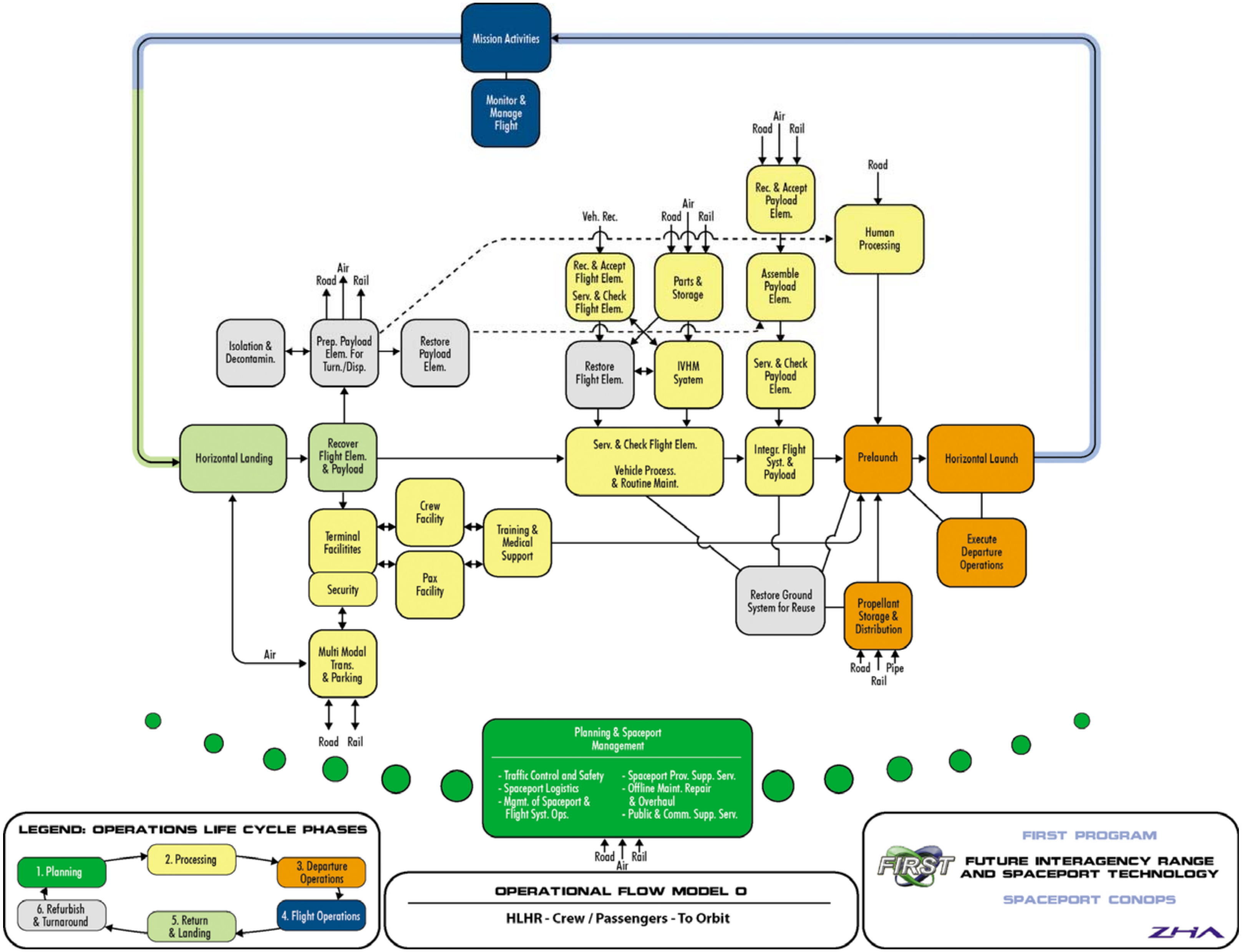


Model N – Horizontal Launch Horizontal Recovery – Crew / Passengers Suborbital – Low Volume – Space Tourism
Model N accommodates the horizontal launch of a reusable launch / flight vehicle carrying crew and passengers on a suborbital trajectory from a runway with limited infrastructure and horizontal return of all components to launch site or other location. Representative programs include horizontally launched X-Prize contenders and related evolving commercial space tourism ventures. **Applicable Design Reference Missions (DRMs) include: Suborbital RLV, and Commercial RLV T&E.**



Model O – Horizontal Launch Horizontal Recovery - Crew / Passengers to Orbit

Model O accommodates the horizontal launch of a crewed reusable launch vehicle to orbit for delivery of passengers and/or payloads for on-orbit activities and return from orbit operations. Vehicle performs reentry and lands at horizontal recovery facility at same location. Representative programs include transports evolved from MSP / HCV-type vehicles performing a variety of operations in the civil and commercial sectors. **Applicable Design Reference Missions (DRMs) include: Space Shuttle to / from ISS, Suborbital RLV, Crew Rescue Mission, and Commercial RLV T&E.**



5.3 OPERATIONAL FLOW MODELS BY PLANNING ERA

Operational Flow Models A through O represent current and future mission configurations spanning the Transformation, Responsive Space Launch and Human Exploration and Mass Public Space Transportation Eras, as presented in Section 2. **Figure 5-2** presents the anticipated timing of each Operational Flow Model with respect to the Planning Eras.

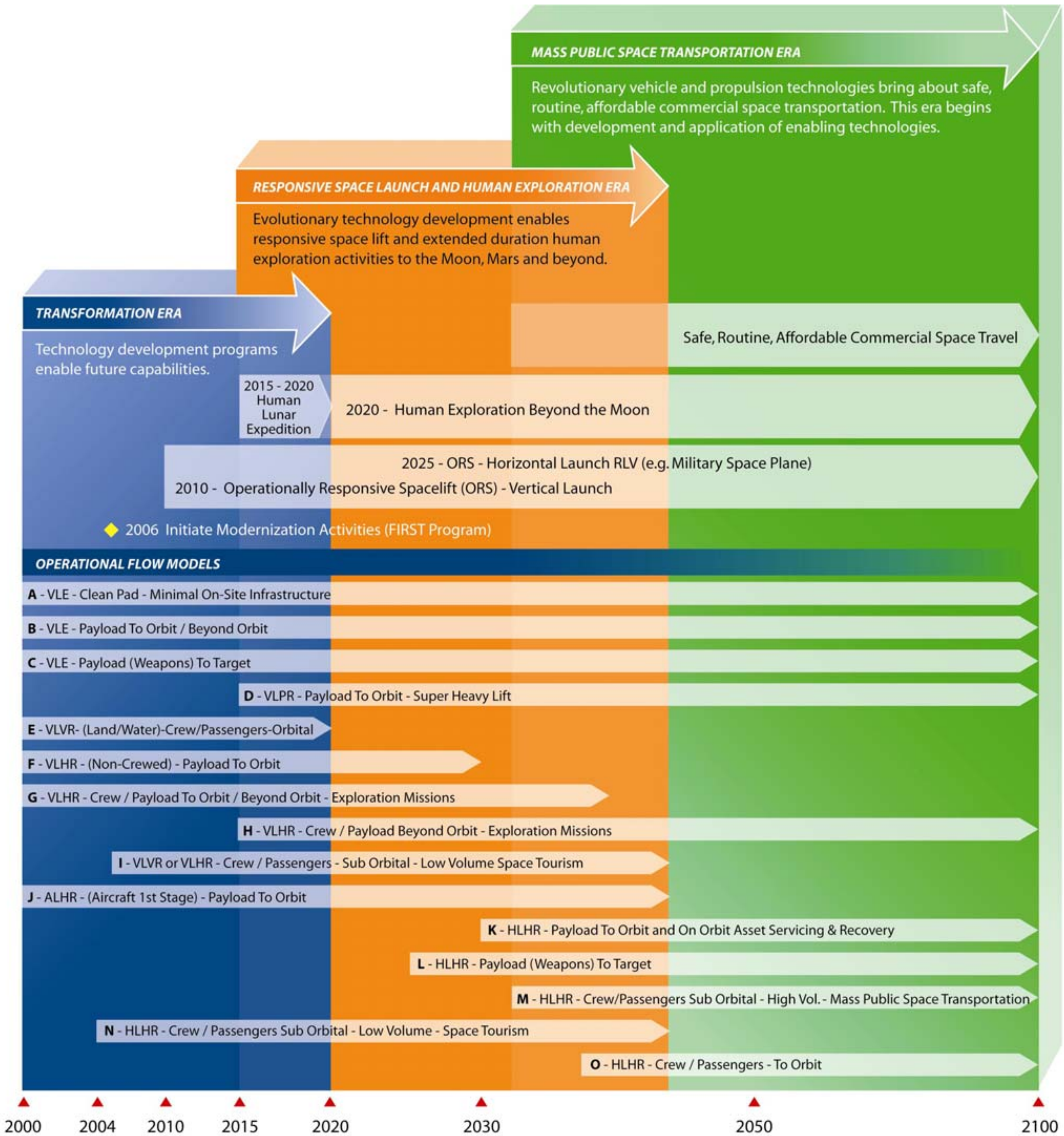


Figure 5-2 Operational Flow Models by Planning Era

The fifteen Operational Flow Models (OFMs) presented herein evolved from the list of Reference Mission Configurations, and define current and future spaceport operational requirements. Each reference mission is assigned to a corresponding Design Reference Mission (DRM) category.

5.4 DESIGN REFERENCE MISSION CATEGORIES

DRM categories refer to the grouping of operational characteristics pertaining to all reference missions. Three DRM categories have been identified to describe the operational characteristics of the reference mission configurations.

- **Routine** - Routine DRMs are scheduled, occur on a planned basis and represent the majority of all spaceport mission operations. Representative examples of routine missions include payload launch to orbit or deep space, launch of an exploration mission and a space tourism flight.
- **Responsive** – Responsive DRMs are unscheduled and occur as the result of the occurrence of an event requiring a space launch response. Representative examples of responsive missions include launch of a missile defense system vehicle, an ORS-PGS launch, launch of a rescue mission, and accomplishing an emergency on-orbit repair or service.
- **Testing & Evaluation** – Testing & evaluation DRMs occur at specialized spaceport locations where new vehicle and component or system development is a part of spaceport activities. Representative examples of testing & evaluation activities include powered or drop flight testing of a new vehicle airframe or propulsion system, static testing of propulsion systems or components or first launch of a new vertical launch vehicle.

Consideration of a reference mission's DRM category is necessary in determining a spaceport's required operational characteristics. Each Operational Flow Model, which evolved from and represents multiple reference mission configurations, must also accommodate the operational requirements associated with one or more DRM categories.

5.5 SPACEPORT OPERATIONAL MODELS

The goal in identifying all potential reference missions and consideration of DRM categories is the creation of one or more spaceport activity flow diagrams, or Spaceport Operational Models, that define the operational characteristics required of a spaceport to meet all related reference mission configuration and DRM category operational requirements. The following Spaceport Building Blocks diagram, **Figure 5-3**, depicts the analytical process used to define the criteria and evaluate the relevant data in developing Spaceport Operational Models to meet the operational needs of an evolving Future Space Transportation System (FSTS).

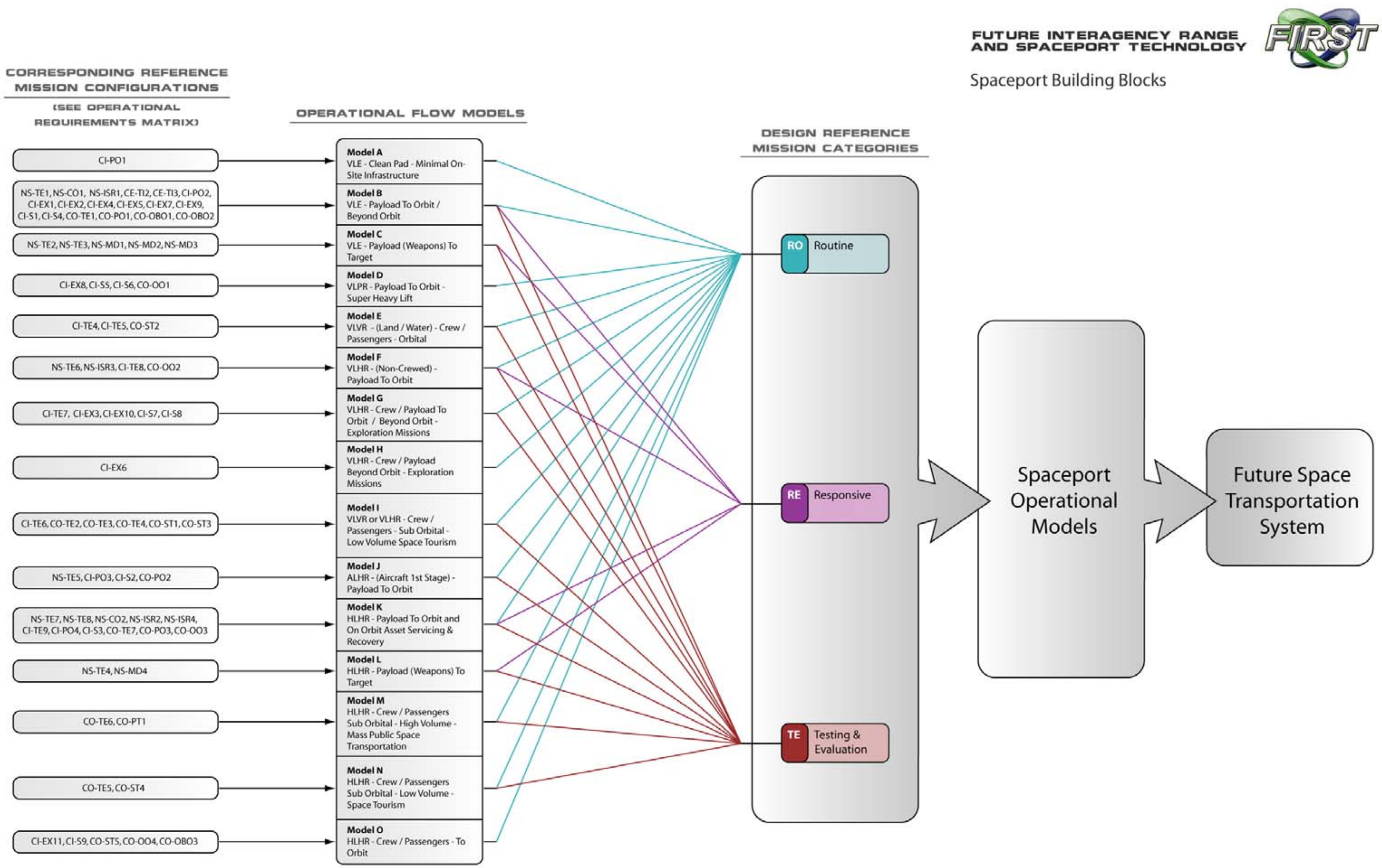


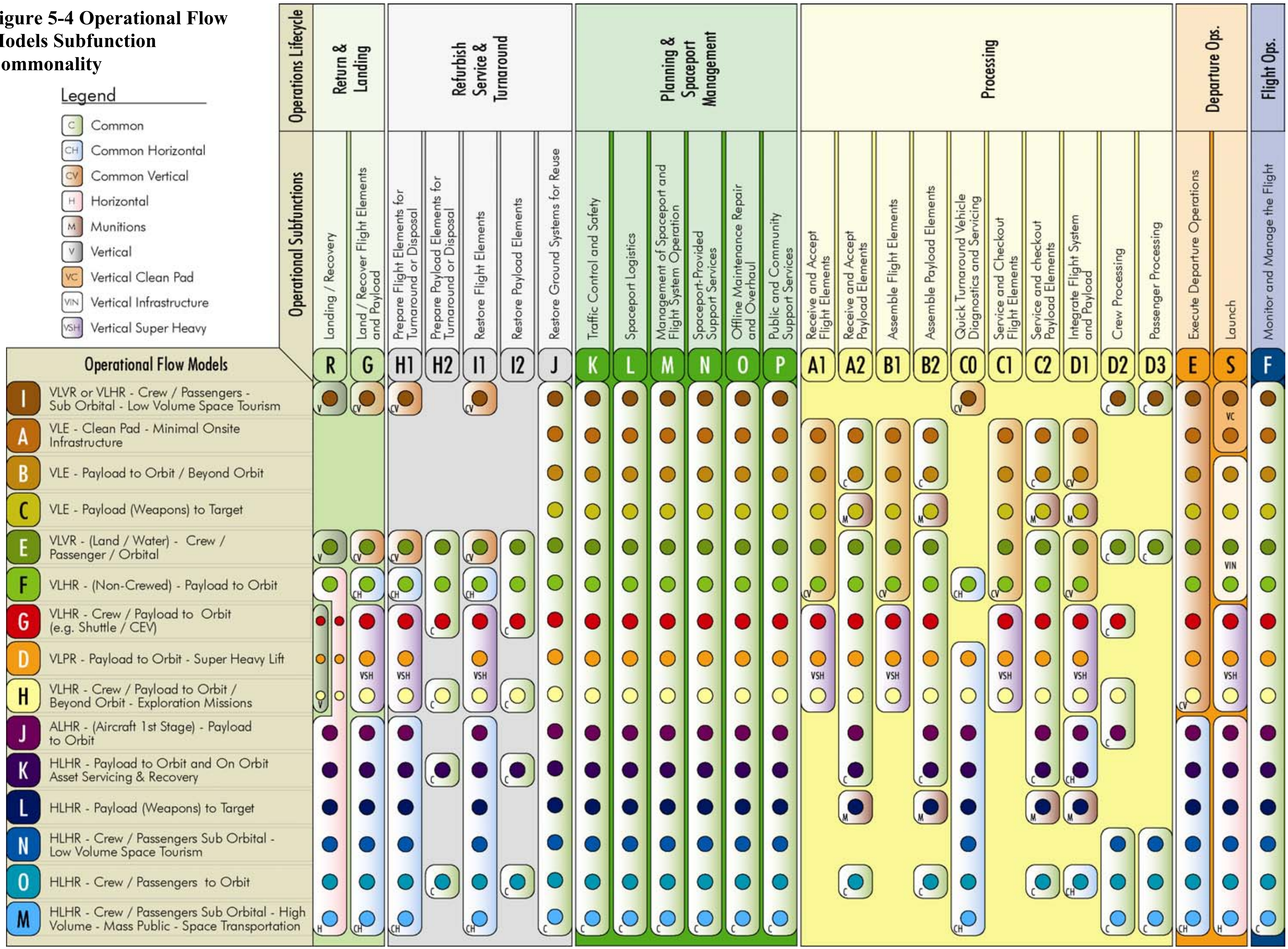
Figure 5-3 Spaceport Building Blocks

The first column, Corresponding Reference Mission Configurations, groups the reference mission configurations identified in the Operational Requirements Matrix according to similar operational requirements. The next column, Operational Flow Models, identifies the flow model developed to meet the operational requirements of the reference mission groups. The next column, Spaceport Operational Requirements, lists the three DRM categories, and shows the relationship between DRM operational requirements and flow model activities. The next column represents the development of Spaceport Operational Models in response to all operational requirements and activities that must be accommodated by a spaceport to meet the operational requirements of the reference mission configurations. The final column represents the Future Space Transportation System (FSTS) supported by the network of spaceports whose operating characteristics are defined by the spaceport operating models.

5.5.1 Operational Flow Models Subfunction Commonality

Development of Spaceport Operational Models from OFMs was initiated by evaluating the flow patterns and activity requirements of each of the 15 OFMs to look for commonality of activities. Each flow model is defined by its operational sub-functions; therefore, a matrix was created to assist in identifying subfunction commonality among the OFMs. Any commonalities identified represent activities that potentially could share spaceport operations and derive common benefit from advances in spaceport technology enhancements. **Figure 5-4,** Operational Flow Models Subfunction Commonality, illustrates the results of the analysis.

Figure 5-4 Operational Flow Models Subfunction Commonality



The rows in the first column beginning at the left margin list the 15 OFMs. The next 26 columns comprise a list of operational subfunctions. For reference, the heading above the subfunctions corresponds to the Operations Life Cycle and how the operational subfunctions relate to the six sequential mission phases of the Operational Life Cycle. The OFMs are color coded for reference. A corresponding colored dot appears in the appropriate columns to the right of each OFM, indicating which operational subfunctions pertain to each OFM.

Next, the dots appearing in each of the 26 subfunction columns were analyzed for operational similarities with the resulting groupings in each column encircled to identify commonalities representing the need for or potential to consider shared activities and thereby, common operations. Following is a summary of the commonality analysis. Letters in parentheses (A,B,C,etc.) indicate OFMs with common activities, or (All) if all are common.

R – Landing / Recovery Facilities

Two recovery mode groups are identified, vertical and horizontal. Vertical recovery locations and means vary with program characteristics including water or land, at launch site or remote, vehicle or components. Provision for vertical recovery is anticipated to be program or vehicle-class specific with the requirement for multiple facilities and locations possible (I,E,G,D,H). Horizontal recovery will become increasingly common as horizontally operating vehicles are introduced to operation with significant potential for utilization of common horizontal recovery facilities (F,G,D,H,J,K,L,N,O,).

G – Land / Recover Flight Elements and Payloads

Three landing and recovery operations groups are identified, driven by program and vehicle requirements. Vertically and horizontally landing vehicles will be processed separately. Vertically landing vehicles will be processed differently based on program requirements with some common facilities (E,I) possible dependent on evolving vertical vehicle development. It is anticipated super-heavy launch vehicle programs (Shuttle-evolved class) (G,D,H) will process separately from other vertically operating programs (stacked). Evolving horizontal vehicles and programs offer the potential for shared recovery processing due to more similarities in vehicle configuration and operating characteristics (F,J,K,L,N,O,). Egress of passengers and crew is accomplished at this time with common passenger and crew facilities provided.

H1 – Prepare Flight Elements for Turnaround or Disposal

Three processing groups are identified. As with recovery operations, vertical and horizontal flight elements will be processed separately. The limited number of vertical programs may be processed through a common facility (E,I), with the exception of super-heavy launch vehicles, which will have dedicated facilities (G,D,H). Horizontal vehicles are anticipated to process through a common facility (F,J,K,L,N,O,).

H2 – Prepare Payload Elements for Turnaround or Disposal

One payload processing group is identified as it is assumed all payloads/cargo returning in vertical or horizontal programs, other than passengers and crew, may be processed through a common down payload processing facility after removal from the vehicle at the vehicle recovery/processing facility (E,F,G,H,K,O).

I1 – Restore Flight Elements

As with recovery and turnaround operations, three groups are identified as it is anticipated vertical and horizontal flight elements will be restored separately. The limited number of vertical programs may be restored through a common facility (I), with the exception of super-heavy launch vehicles, which will have dedicated facilities (G,D,H). Horizontal vehicles are anticipated to process through a common facility (F,J,K,L,N,O,).

I2 – Restore Payload Elements

One group is identified as it is assumed all returning payload elements may be restored in a common payload processing / refurbishment facility (E,F,G,H,K,O).

J – Restore Ground Systems for Reuse

It is anticipated restoration of ground systems will be the responsibility of a common facilities and infrastructure maintenance entity (All).

K - Traffic Control and Safety

It is assumed this supporting subfunction will apply to all flow models and the overall spaceport.

L – Spaceport Logistics

It is assumed this supporting subfunction will apply to all flow models and the overall spaceport.

M – Management of Spaceport and Flight System Operation

It is assumed this supporting subfunction will apply to all flow models and the overall spaceport.

N – Spaceport-Provided Support Services

It is assumed this supporting subfunction will apply to all flow models and the overall spaceport.

O – Offline Maintenance Repair and Overhaul

It is assumed this supporting subfunction will apply to all flow models and the overall spaceport.

P – Public and Community Support Services

It is assumed this supporting subfunction will apply to all flow models and the overall spaceport.

C0 – Quick Turnaround Vehicle Diagnostics and Servicing

Two groups are identified. It is anticipated with the increase in the number of reusable vehicles with more robust systems and integrated diagnostics and monitoring equipment, many returning vehicles will require only systems checks and minor servicing between routine flight operations. This is considered especially viable for horizontally operating vehicles, where development of a common operation is suggested (F,D,H,J,K,L,N,O,). Vertical reusable vehicles would likely be serviced in a similar operation for vertical vehicles (I).

A1 – Receive and Accept Flight Elements,

It is envisioned the model spaceport will have common facilities for receiving and accepting most vehicles and flight elements arriving at the spaceport, including all vertically launched vehicles (A,B,C,E,F) except super-heavy components, which would be tracked through the same facility but received and handled in dedicated program facilities (G,D,H). It is assumed horizontal operating reusable vehicles would arrive at the spaceport as assembled, operational units, and as such, could be received by the common facility through remote check-in and immediately move to horizontal servicing for checkout and operational status certification. At the completion of check-in or other time appropriate to specific programs, launch vehicle components would be forwarded to common vertical assembly or program super-heavy assembly operations.

B1 – Assemble Flight Elements, C1 - Service and Checkout Flight Elements

Two groups are identified for vehicle assembly and checkout. After receipt and check-in at A1, vertical launch vehicles (A,B,C,E,F) would be forwarded to a common vertical vehicle assembly and checkout process. Super-heavy components, which would be tracked through the same receiving operation, would be received and handled in dedicated program facilities (G,D,H) where assembly and checkout would occur. At the completion of checkout or other time appropriate to specific programs, the assembled launch vehicles would be transferred to integration facilities.

A2 – Receive and Accept Payload Elements, B2 – Assemble Payload Elements, C2 – Service and Checkout Payload Elements

Two groups are identified for payload processing. It is also envisioned the model spaceport will have common facilities for receiving, accepting, assembling and servicing most payloads and payload elements arriving at the spaceport, regardless of vehicle type or program (A,B,E,F,G,D,H,J,K,O). One exception would be DOD munitions payloads (C,L), which would be received, handled, stored and processed at a secure, separated safe location. At the completion of checkout or other time appropriate to specific programs, the assembled payload would be transferred to program integration facilities.

D1 – Integrate Flight System and Payload

Four groups are identified for vehicle / payload integration. It is assumed once vehicles and payloads are processed, integration will occur in facilities more directly related to vehicle mode of operation and program. Vertical vehicles will integrate in a common facility (A,B,E,F), as will the super-heavy program vehicles (G,D,H). Horizontal vehicles will integrate in a common facility (J,K,O) while DOD operations with munitions payloads (C,L) will integrate in a separate, remotely located facility.

D2 – Crew Processing

One group is identified for crew processing as it is assumed common facilities can meet the needs of varying programs (I,E,G,H,J,N,O,).

D3 – Passenger Processing

One group is identified for passenger processing as it is assumed common facilities can meet the needs of varying programs (I,E,G,H,J,N,O,).

E – Execute Departure Operations

Two groups are identified as it is assumed there will be operational differences between horizontally (J,K,L,N,O) and vertically (I,A,B,C,E,F,G,D,H) launched vehicles requiring different support infrastructure, with many opportunities for commonality within the two groups and opportunities for shared infrastructure by both groups.

S - Launch

Four groups are identified: vertical launch with clean pad / minimal infrastructure (I,A), vertical launch requiring infrastructure at the pad or as part of a transporter/launch platform connected to services at the pad (B,C,E,F), vertical launch with extensive infrastructure at the pad for super-heavy launch (G,D,H), and horizontal launch from a runway (J,K,L,N,O).

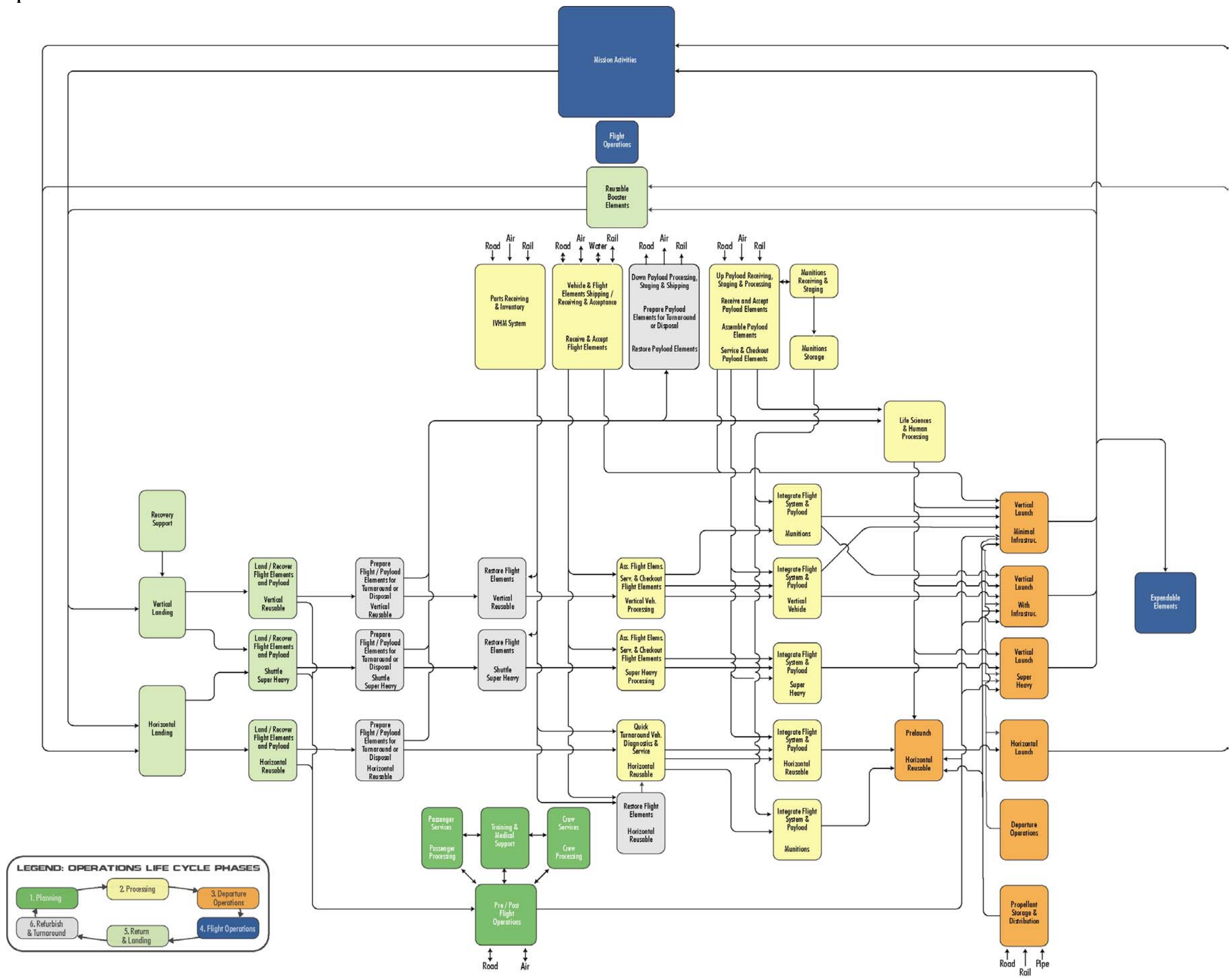
F – Monitor and Manage the Flight

One group is identified as it is assumed all operations in progress can be controlled / managed from one facility (All).

5.2.2 Spaceport Base Operational Model

Using the 15 Operational Flow Models and information generated by the evaluation of Operational Flow Models Subfunction Commonality, a spaceport flow model was developed to graphically depict the interrelationships and component flow patterns between the subfunctional elements of the 15 OFMs that describe an operational spaceport. The model diagram addresses mission requirements in a way that maximizes commonality of activities and the potential benefits of applied technology enhancements. Following is the resulting Base Operational Model (BOM), **Figure 5-5,** and a description of the process represented.

Figure 5-5 Base Operational Model



The BOM diagram is a representation of the activities and process flow required at the model spaceport to accommodate mission operational requirements described by all of the 15 OFMs. Because the BOM is planned to accommodate all flow models, it provides necessary activities for all missions through three planning eras. Actual spaceports planned using the baseline model as a guideline would not necessarily include all the subfunctional elements shown in the baseline model, but would include the subfunctions necessary to meet operational flow model requirements for the missions planned at any one particular spaceport during the appropriate planning era.

The process flow indicated in the BOM moves from left to right through the diagram, as returning vehicles or components return to the spaceport (far left), are recovered, processed, prepared for launch, and are launched (far right). Mission activities are represented by the loop rising from launch to the top right of the diagram and descending from the top left to the recovery activity.

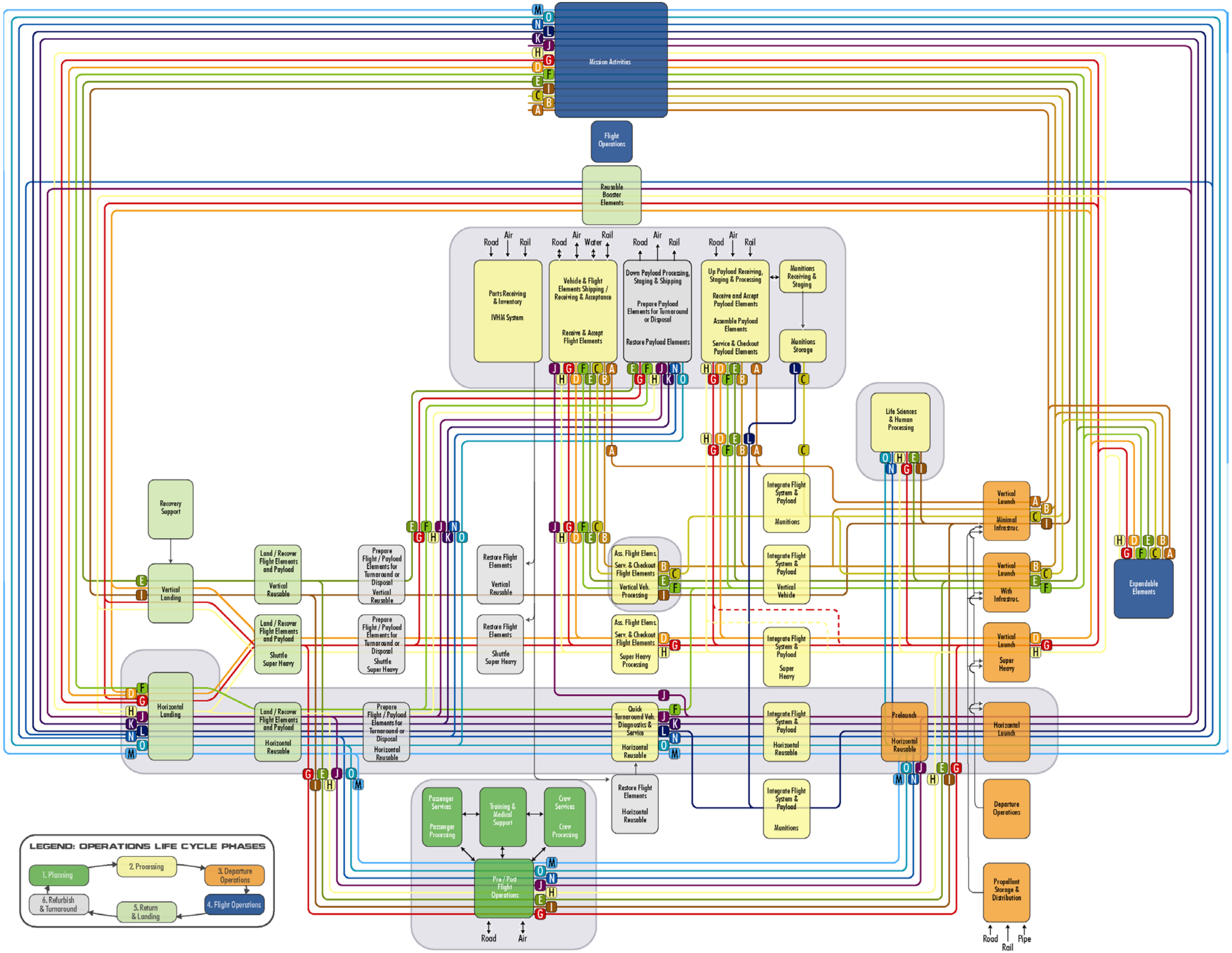
5.2.3 Spaceport Base Operational Model with OFM Overlay

As a test of the BOM, each of the 15 OFMs were overlayed on the BOM to verify all OFM subfunction area and process flow requirements were accommodated. The resulting overlay is depicted in **Figure 5-6**. The overlay shows the flow line of each OFM as it passes through the pertinent subfunctions of the Spaceport Base Operating Model, leaves the spaceport to complete its mission, and returns to the spaceport (or recovery location), completing the cycle. Through this test it was confirmed the BOM meets all OFM requirements.

The overlay also graphically depicts the subfunctions within the BOM with the greatest concentrations of OFM lines representing the greatest levels of shared subfunction activities and thereby, the greatest potential for shared benefit from applied enabling technologies. These areas include:

- Up and down payload shipping and receiving / assembly / checkout
- Vehicle and vehicle component receiving, acceptance, and processing
- Parts and component receiving / storage / distribution
- Movement and processing of horizontal vehicles generally (as horizontal reusable vehicles become a predominant presence at spaceports in second and third eras)
- Handling and assembly / disassembly of vertical vehicles, components, and payloads (due to the extensive activities throughout the vertical process)

Figure 5-6 Base Operational Model with OFM Overlay



5.2.4 Spaceport Component Models (SCMs)

The Base Operational Model responds to and accommodates the mission requirements of all 15 OFMs. It is anticipated future market demand, driven by evolving vehicle technologies, emerging markets, and safety and security issues, will result in the spin-off of Spaceport Component Models, which respond to the specific operational requirements of one or more (but not all) OFMs to generate specialized Spaceport Component Models. The following four examples represent potential spin-off SCMs.

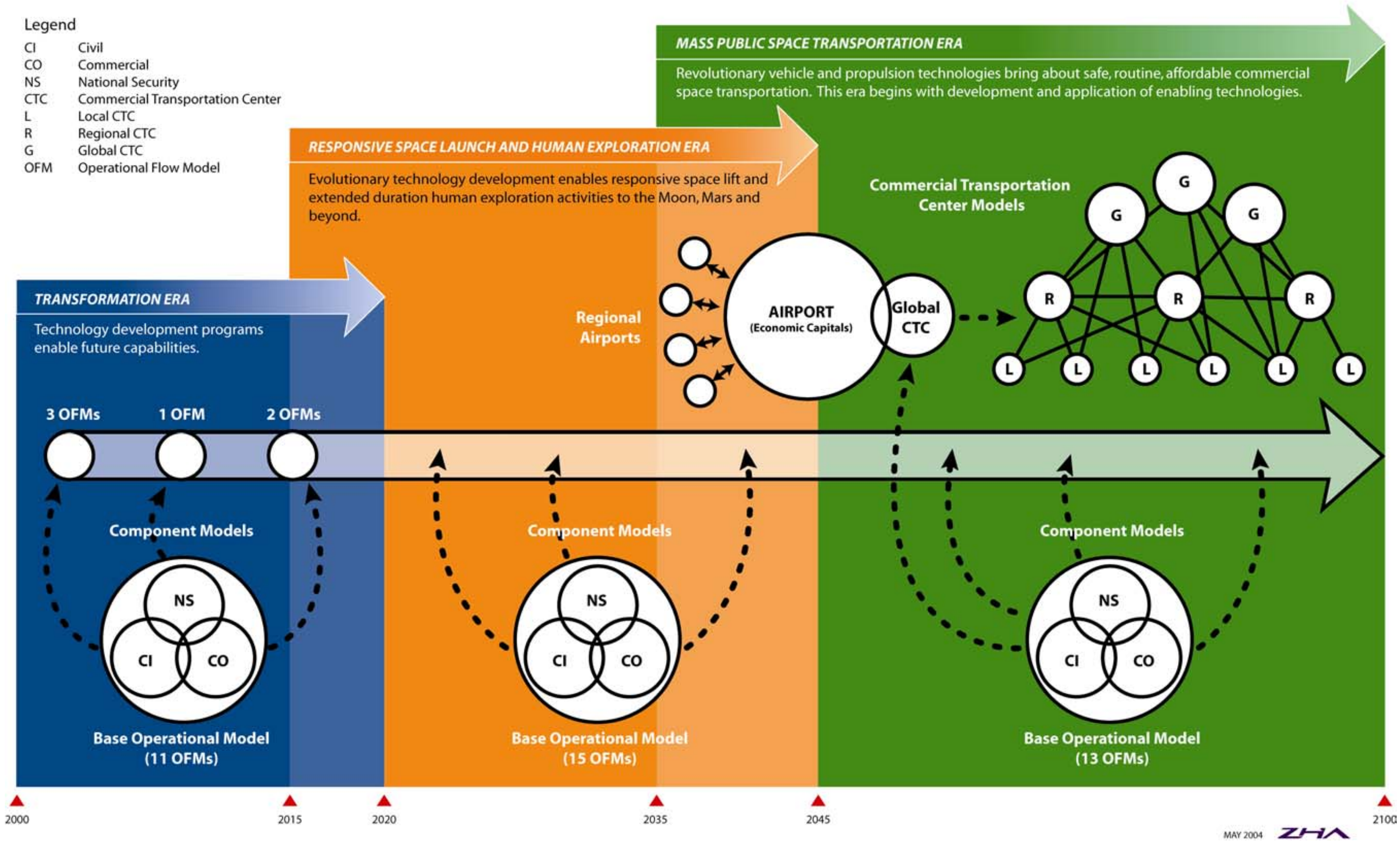
Figure 5-7 Spaceport Component Models by Planning Era, summarizes the envisioned development of spaceport models by planning era in which a base operational model (BOM) accommodating numerous diverse mission requirements evolves over time with new technology-infused benefits. The BOM supports spin-off component models driven by market and mission demands with the most significant evolution of the FSTS coming in the third era, an era in which a global network of component models referred to as Commercial Transportation Centers (CTCs) evolve, ushering in an age of mass public space transportation.

<u>NS National Security (Military) Spaceport</u>

The national security SCM could be comprised of any combination of OFMs "B, C, F, J, K and L", defining the requirements of an operation wherein the primary mission is to provide support services for operational and developmental (T&E) national security programs and related military operations. Operations are highly secured and physically separated from adjacent non-secure facilities and population centers. Both horizontally and vertically launched programs will routinely operate on a scheduled low frequency basis, however, the operation will also accommodate on-demand high frequency operationally responsive program requirements. Activity accommodations are adequate to assure redundancy of all mission-critical operations and supporting elements. Priority access to the national air and space control system (range) is required. Mission scopes accommodated would include: ORS munitions delivery-to-target, launch to orbit of ORS-ISR surveillance and identification operations, and ORS launch-to-intercept defense systems; launch of communications and control satellites to orbit; and testing & evaluation operations related to the development of national security systems. A national security SCM would be characterized by the following attributes:

- Public access – highly restricted
- Security level – highly restricted access to all areas
- Hazard level – high with significant hazard separation required
- Noise generation level – high with significant noise separations required
- Testing & evaluation component
- Priority access to airspace & range
- Redundancy of mission-critical systems required
- Vertical and horizontal operations
- Munitions delivery to target
- Port facilities required for some programs
- Low frequency of operations – routine
- High frequency of operations – responsive

Figure 5-7 Spaceport Component Models by Planning Era



CSR Civil Space Exploration, Science & Research Spaceport

The civil space exploration, science & research SCM could be comprised of any combination of OFMs "A, B, D, E, F, G, I, J, and K", defining the requirements of an operation wherein the primary mission is to provide support services for operational and developmental (T&E) civil programs in the areas of space exploration, science and research. Program operations are highly secured while some related research and public outreach functions allow unrestricted access. Program areas are physically separated from public activities and population centers. Both horizontally and vertically launched programs will routinely operate at the facility on a scheduled low frequency basis, however facilities will also accommodate on-demand operations responsive to program mission requirements. Scheduled access to the national air and space control system (range) is required. Mission scopes accommodated would include: launch of satellites, probes, and robotic landing craft on reconnaissance missions to the moon, planetary destinations and deep space; launch of exploration missions to the moon and planetary destinations; launch of support missions to the International Space Station; launch of civil payloads including science and experimentation missions to various Earth orbits; responsive launch of on-orbit rescue missions; and T&E activities related to the development of new and evolving technologies in support of civil space endeavors. A civil space exploration, science & research SCM would be characterized by the following attributes:

- Public access - controlled with public outreach component
- Security level – restricted access to all program areas
- Hazard level – high to moderate with significant separations required
- Noise generation – high with significant noise separations required
- Testing & evaluation component
- Scheduled access to airspace & range
- Scheduled operations with responsive component
- Redundancy required
- Vertical and horizontal operations
- Port facilities required for some programs
- Low frequency of operations – routine
- Low frequency of operations – responsive

CO Commercial Operations Spaceport

The commercial operations SCM defines facilities wherein the primary mission is to provide infrastructure and facilitate access to space for a variety of commercial ventures and operations similar to those that might be found in an airport industrial park. Access would be controlled with regard to airfield and launch infrastructure and unrestricted to the facilities operating with a public interface. Separation requirements will vary with program elements, as the potential exists for some vehicles operating at the facilities to generate high noise levels or handle hazardous cargos. While it might be possible for some facilities to be located near population centers, the generally commercial/industrial nature of the activities envisioned for these facilities suggest large remote areas with suitable transportation connectors to population centers might be the preferred approach. Horizontally and vertically launched programs could operate at the facility, although the potential for operating conflicts exists which could restrict capacity utilization or dictate significant separations between vertical and horizontal facilities. The facility should operate at a relatively high frequency for routine scheduled operations and will also provide for a low frequency responsive launch component. Examples of mission scopes accommodated include: hypersonic cargo transportation and distribution to transcontinental / intercontinental destinations; commercial / contract payload launch to a variety of Earth orbits; ground support and launch facilities in support of on-orbit scientific, research, manufacturing or on-orbit spacecraft refueling / repair / recovery operations; ground terminal and launch facilities in support of space tourism and space burial operations; handling and disposal of hazardous waste via launch to solar / deep space destination; and facilities and access to launch in support of commercial development, testing and evaluation of new and evolving launch and space vehicle programs. A commercial operation SCM would be characterized by the following attributes:

- Access – combination of restricted and publicly accessible areas
- Hazard level – high to minimal with varying safety separations required
- Noise generation – high to minimal with some significant noise separations required
- Low cost / easy access-to-space
- Vertical & horizontal launch
- Scheduled operations with responsive component
- Moderate frequency of operations – routine
- Low frequency of operations - responsive
- Testing & evaluation component
- Rent / lease facilities available for assembly, integration & launch
- Availability of shared-use facilities
- Commercial development of facilities with access to launch infrastructure
- Commercial payloads to orbit
- On-orbit repair & servicing

CT Commercial Transportation Centers

The commercial transportation center SCM would represent the operational requirements of OFM “M”, defining an operation which integrates next-generation technology horizontal launch and recovery hypersonic vehicles into the commercial airport transportation network, extending beyond terrestrial destinations to include sub-orbital trips and on-orbit destinations. It is envisioned existing airports will become commercial transportation centers, functioning essentially as commercial airports with the addition of hypersonic interconnection. For this to occur, evolving hypersonic vehicle operating characteristics must allow assimilation into existing airport operations, especially as related to airfield requirements, operational hazards and noise.

It is also anticipated multiple variations of the commercial transportation center will evolve in response to varying market demand, just as airports vary to meet user requirements. In addition to terrestrial transportation, evolving technologies are expected to foster the development of sub-orbital and on-orbit space tourism industries requiring ground bases of operation.

The facilities will be subject to the same security requirements and concerns as conventional international airports. Facilities would be located convenient to population centers with horizontally launched vehicles operating on a scheduled, high frequency basis. Scheduled continuous access to the national air and space control system (range) would be required. Mission scopes accommodated would include routine passenger air travel combined with hypersonic transcontinental and intercontinental passenger travel, hypersonic passenger travel to near orbit and orbital destinations, and other viable evolving launch systems providing for space tourism opportunities to near-orbit or on orbit destinations. These models address operational support for certified flight vehicles and do not contain a T&E component. A commercial transportation center SCM would be characterized by the following attributes:

- Access – highly accessible w/ restricted airfield/launch areas
- Hazard level – may vary with moderate safety separations required
- Noise generation - Near population centers (low noise generators & compatible operations)
- Inter-modal transportation component
- Routine scheduled vehicle operations
- Access to air traffic control and range
- High frequency routine operations for horizontal operation only facilities
- Exclusively horizontal operations – at current airport network
- Space tourism terminal operations

The Evolution of Mass Public Space Transportation

As the third planning era of Mass Public Space Transportation approaches and evolves, the FSTS will effectively shrink geographic distances on earth, reducing transcontinental and transoceanic trip time from numerous hours or days to less than two hours. Market logistics and economies of scale will promote the implementation of increasingly advanced hypersonic vehicle operations that are easily integrated into the infrastructure of the future spaceport system without operational restrictions.

The FSTS is envisioned to include a global network of Commercial Transportation Centers that evolved from Airports of the past. These CTCs are component models that spin off from the spaceport base operational model in order to support hypersonic air and space travel through the common use of facilities and system infrastructure on high frequency and market proximate bases. These various markets are served by CTCs that are scaled in size (tiered) to address passenger and cargo volumes resulting from ever-changing market logistics as well as technology enabled vehicle capabilities. The former distinction between airports and spaceports is now erased in the third planning era with the functionality of those two previously unique systems integrated into one superior, evolved future system that is safe and affordable, efficient and reliable, and meets the expectations of all users through consistent service levels.

The vision for the CTC network leverages today's traditional airport network by first integrating new vehicles and capabilities into few, then many, large global markets followed by expansion of hypersonic vehicle transport into regional, and ultimately, local airport markets. Specifically, as hypersonic suborbital space travel becomes more reliable through technology innovation and consistent vehicle performance, suborbital service will debut between major world economic capitals effectively shrinking global distances and opening up further global trade. Initial commercial transportation centers, identified as <u>global and on-orbit CTC hubs</u>, will represent the first tier of a network that leverages a mature aviation industry hub and spoke system in order to capitalize on feeder systems from regional and local airports to the largest base markets worldwide.

As the initial CTC hub market matures, a second tier of <u>regional CTCs</u> will develop within the network, implementing point-to-point service in addition to the major trunk routes established by the initial global hub suborbital service. Here, the natural evolution of the industry is realized in which second tier markets infill the existing global and on-orbit CTC framework to provide greater depth to the system. The movement of cargo becomes more robust in this period in which conventional aircraft begin to phase out with evolved vehicles coming online.

The next evolution of the market's development will see a third tier of local service CTCs within the network that ultimately host evolved technology vehicles that promote the phase out of conventional aircraft. These evolved vehicles will serve the former conventional aircraft markets and are supported by efficiencies realized through new technologies and the achievement of economies of scale at all tiers of the CTC network.

Mass Public Space Transportation Demand

As part of the CONOPS, an evaluation was conducted in regard to the initial future market demand for mass public space transportation. Scenario analyses were conducted drawing from historical growth and decline and forecast cycles in aviation industry passenger and cargo traffic to project potential activity levels based on assumptions regarding the future world economic climate.

These future traffic projections for routine suborbital hypersonic transport were reviewed to identify the potential order-of-magnitude demand for future CTC infrastructure within a viable market context.

Using economic and aviation activity data from seven of the world's economic capitals and their respective principal agglomerations, three scenarios were developed to evaluate the potential shift of conventional aviation passengers to an evolving reliable, safe hypersonic market in the 2040 timeframe. For purposes of this high level evaluation, the existing market share of world aviation passenger activity held by the seven economic capitals was assumed to remain constant at 14.4% throughout the evaluation period. This is to say, the seven markets evaluated represent 14.4% of total world aviation passenger levels.

To develop the projections for the 2040 timeframe, assumptions were made that drove three different scenarios: baseline, conservative and aggressive. These assumptions included: percent shift of passengers from conventional air travel to hypersonic travel, vehicle capacity, vehicle load factor, escalation of existing activity levels to 2040, and the percent of daily operations assigned to the daily peak period. The calculated average number of daily hypersonic departures and daily peak activity at each world economic capital reveals the minority position of hypersonic travel to conventional air travel in the inaugural stage. This evaluation further suggests that relationship will change as the CTCs evolve and regional and local hypersonic service routes are added within the network, replacing former conventional air routes and further eliminating the traditional definition of airports and spaceports specific to mass public space travel.

Logistics

In conjunction with these projections for hypersonic transport activity levels, flight times were estimated between the seven markets in order to test whether the logistics of the hypersonic transport technology in the marketplace were supportable. Previous supersonic service that approached Mach 2 (the Concorde) ultimately failed due to an unsupportable business model and inefficient vehicle servicing. Furthermore, the Concorde's diseconomies of scale, limited fleet of 16 aircraft, and a fatal accident were significant in retiring the vehicle. For the CONOPS, flight times between markets were estimated at two potential average aircraft speeds of 2500 mph and 4000 mph, speeds believed to be achievable by hypersonic aircraft. Comparing the average flight times at these speeds to those of conventional aircraft suggested the initial business case for suborbital mass public space travel could tap into the established aviation network and hub in major markets to leverage existing feeder routes. The flight times indicated a business model in which conventional air travel would hub and then connect to hypersonic trunk routes might be supportable. Longer haul routes were generally selected to capitalize on economies of scale associated with operating hypersonic aircraft over greater distances while leveraging conventional air travel over shorter regional and local routes. In general, the tradeoffs between ticket price and door-to-door travel timeframes support the integration of hypersonics with conventional air service to capture part of the existing and growing air transportation market.

Ultimately, these high level evaluations along with market context and logistics support the spin-off of routine mass public space transportation operations to the CTC component model. Through this spin-off from the base operational model, the necessary economies of scale and market access needed to support the future business case of mass public hypersonic transport appear to be most viable.

Appendix 3 presents the economic data considered, average flight time analysis, and resulting demand projections for each of the three mass public space transportation demand scenarios.

Appendix 4 provides a snapshot of what the inaugural CTC markets and 1st tier network could look like in the third planning era of mass public space transportation. Potential hypersonic routes are shown in black overlaid on top of the conventional air transport network shown in red.

6.0 "DAY IN THE LIFE" SCENARIO

The "day in the life" story in this section describes how future spaceport operations and activities are conducted using the envisioned future spaceport to support multiple types of operational space transportation missions and flight test activities. These examples were chosen from the three Design Reference Mission (DRM) categories associated with this CONOPS to highlight how future spaceports will operate as an integrated system **(See Figure 6-1)**. The DRM categories associated with this CONOPS are:

1. Routine Space Flight Operations
2. Responsive Space Flight Operations
3. Flight Test & Evaluation Activities

Each DRM illustrates the scope of activities the future spaceport supports, and highlights which types of missions stress spaceport capabilities.

Three Design Reference Missions Categories address routine, responsive and T&E operations.

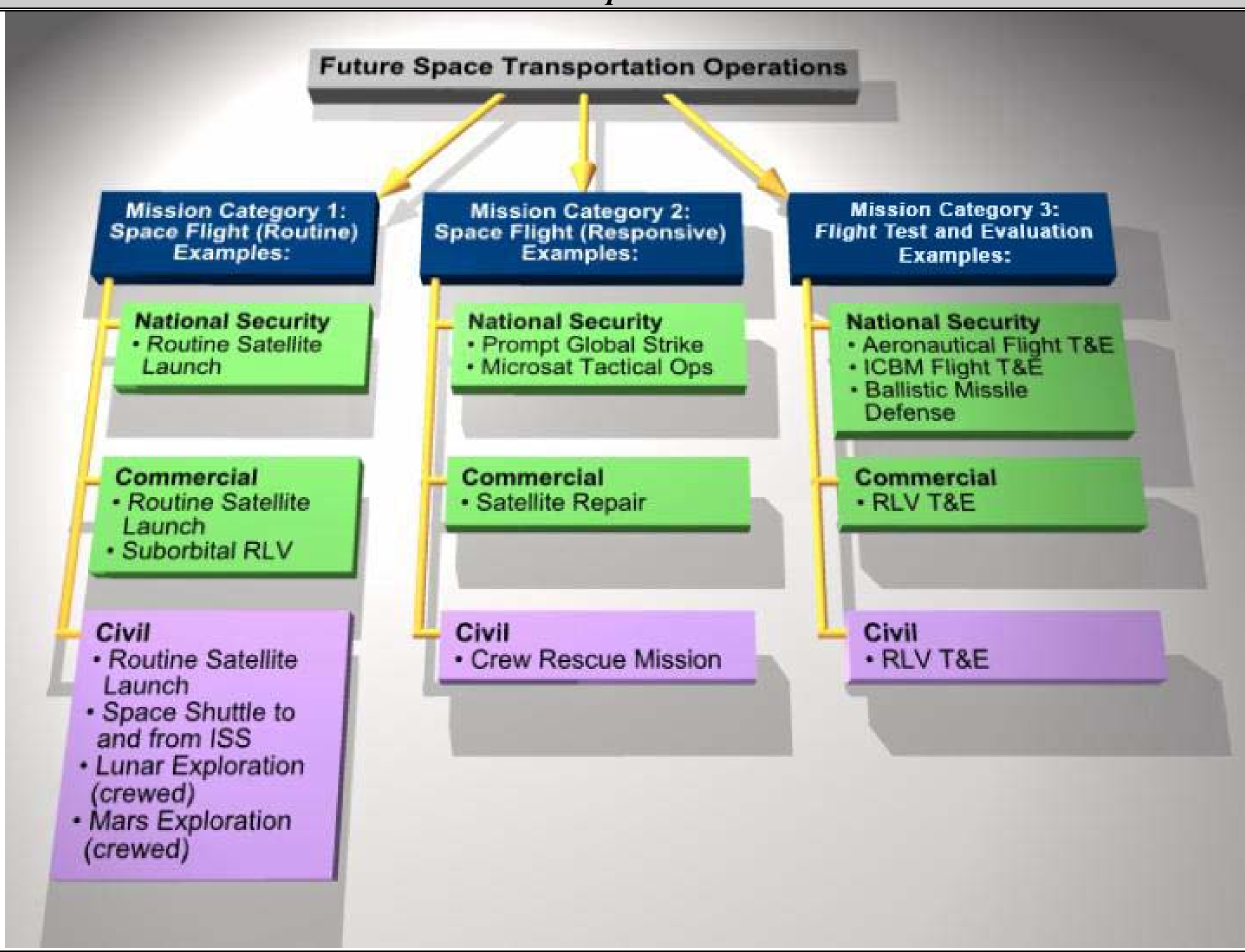


Figure 6-1 Design Reference Missions Categories and Example Missions

The scenario described in this section highlights several examples of missions derived from the DRMs, but it only depicts one day's operations. The context for that day's operations is depicted in the year-long schedule of activities in **Figures 6-2 and 6-3**, which highlight the importance of the ability of future spaceports to support frequent and multiple concurrent operations.

A typical future year, as conceptually envisioned, will include many routine, responsive, and test missions, with frequent overlapping and concurrent operations.

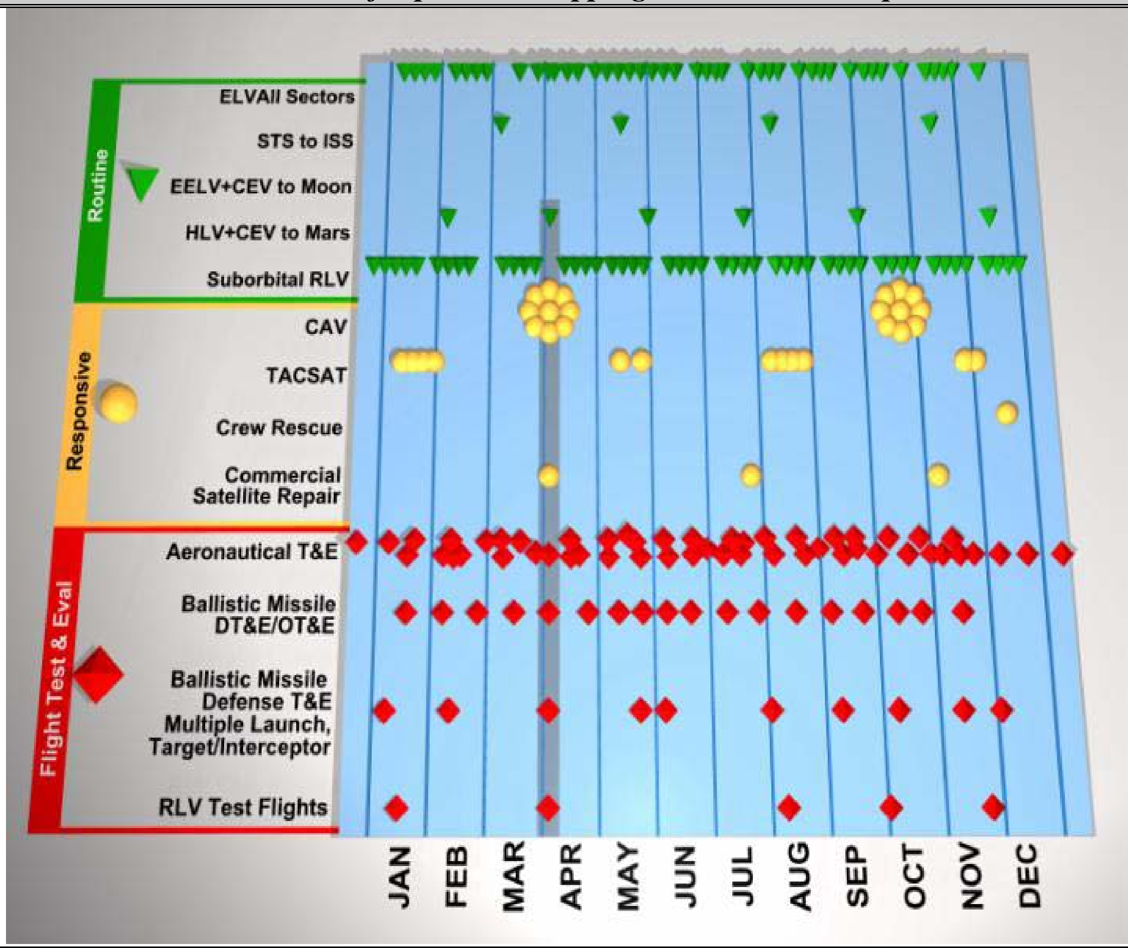


Figure 6-2 Example Mission Scenario for a Future Year

Each example mission described in this section was chosen to illustrate specific characteristics of future spaceport operations, how particular functions and capabilities are employed in support of each of the DRMs, and how the system of spaceports provides responsive, flexible, adaptable capabilities to support a variety of missions and activities, when needed anywhere in the world.

These examples were chosen from among the many possible example missions for each DRM to illustrate the specific ways that each DRM stresses future spaceport capabilities in terms of each of the performance characteristics identified in the Needs Assessment.

The scenario described in this section includes examples to illustrate the operations associated with each of these missions, including interactions among them when operations overlap and require concurrent support.

The six specific mission examples are:

1. Routine commercial suborbital RLV flight

A routine, regularly scheduled suborbital commercial space tourism flight from Oklahoma to California illustrates the need for future spaceports to provide enhanced capabilities in terms of:

- Flight Rate—dozens of suborbital flights per year in the second era, characterized by responsive space launch and human exploration, and hundreds to thousands in the third era, characterized by mass public space travel
- Responsiveness—frequent flights, changes to flight plans, contingency operations to accommodate unplanned landings, facilitated via enhanced processing, support and delivery systems infrastructure to increase launch capacity and reduce processing time
- Standardization/Interoperability—to enable point-to-point flights of multiple vehicle types to a variety of facilities, service a variety of vehicles at each location fast and efficiently, and develop common ground support equipment and systems for each spaceport
- Evolve Safety—to enable flights of commercial RLVs over population centers and safely return passengers, and enhance the safety of maintenance, service, launch and other ground support operations
- Flexibility/Adaptability—to support operations to and from new locations with flexible common use facilities
- Concurrent Operations—to routinely accommodate multiple simultaneous launches and landings, to accommodate the timely service and maintenance of multiple vehicles, and schedule/control multiple simultaneous operations
- Optimize Cost—to enable development of commercial tourism, package delivery, and other markets through technological enhancements to improve efficiency of flight system and payload handling, processing, service and maintenance, and launch and recovery operations, and to reduce the cost of supporting infrastructure equipment and systems

2. Routine scheduled NASA launch to support a crewed mission to the Moon

A scheduled launch of a NASA crew exploration vehicle (CEV) aboard an Evolved Expendable Launch Vehicle (EELV) to embark on a crewed mission to the Moon illustrates the need for improvements in:

- Evolve Safety—to enable flights of crewed vehicles on expendable boosters, and enhance the safety of maintenance, service, launch and other ground support operations

- Concurrent Operations—to routinely process multiple vehicles simultaneously, and to accommodate the timely service and maintenance of multiple vehicles, and schedule/control multiple simultaneous operations
- Optimize Cost—to enable an affordable human exploration program through technological enhancements to improve efficiency of flight system and payload handling, processing, service and maintenance, and launch and recovery operations, and to reduce the cost of supporting infrastructure equipment and systems

3. Routine scheduled NASA launch to support a crewed mission to Mars

A scheduled launch of a NASA Shuttle-derived super heavy lift launch vehicle to lift some spacecraft elements into orbit to support a crewed mission to Mars illustrates the need for improvements in the following areas:

- Evolve Safety—to enable flights of crewed vehicles on expendable boosters, and enhance the safety of maintenance, service, launch and other ground support operations
- Concurrent Operations—to routinely process multiple vehicles simultaneously, and to accommodate the timely service and maintenance of multiple vehicles, and simultaneously schedule/control multiple varying operations
- Optimize Cost—to enable an affordable human exploration program through technological enhancements to improve efficiency of flight system and payload handling, processing, service and maintenance, and launch and recovery operations, and to reduce the cost of supporting infrastructure equipment and systems.

4. Operationally Responsive Spacelift (ORS) Prompt Global Strike (PGS) missions

Operationally Responsive Spacelift (ORS) missions to inspect a damaged spacecraft in orbit and to deliver Common Aero Vehicle (CAV) prompt global strike platforms in response to foreign acts of aggression on United States interests illustrate the need for the future range to provide enhanced capabilities in terms of:

- Flight Rate—10 or more launches/missions per day and dozens per week. By far the most intense short-term flight rate requirement of any planned mission type in the first and second eras.
- Responsiveness—launch within hours of notification in the first and second era and within minutes of notification in the third era, facilitated via enhanced processing, support and delivery systems infrastructure to increase launch capacity and reduce processing time

- Global Coverage—to provide a sufficient number of spaceports globally to support the mission goals with common support capabilities and operational interconnection
- Standardization/Interoperability—to enable use of multiple spaceports, each capable of servicing and launching common vehicles rapidly and efficiently by developing common ground support equipment, systems, and infrastructure for each spaceport
- Evolve Safety—to enable responsive launches during development, operational testing, and operations in response to threats, and enhance the safety of maintenance, service, launch and other ground support operations
- Flexibility/Adaptability—to accommodate frequent missions and to accommodate new classes of vehicles as they come on line
- Concurrent Operations—to routinely accommodate multiple simultaneous processing and launches/recoveries, and to accommodate the timely service and maintenance of multiple vehicles, and simultaneously schedule/control multiple varying operations
- Optimize Cost—to enable development and use of CAV when needed through technological enhancements to improve efficiency of flight system and payload handling, processing, service and maintenance, and launch and recovery operations, and to reduce the cost of supporting infrastructure equipment and systems.

5. Flight test of a new prototype DoD Hypersonic Cruise Vehicle (HCV)

A flight test of a new prototype DoD Hypersonic Cruise Vehicle (HCV) in development illustrates the need for future spaceports to provide enhanced capabilities in terms of:

- Responsiveness—aeronautical systems typically undergo multiple flight tests per day, requiring constant schedule flexibility and short-notice re-scheduling of launches, recoveries, and spaceport support facilitated via enhanced processing, support and delivery systems infrastructure to increase launch capacity and reduce processing time
- Flexibility/Adaptability—preparation and ground support of a variety of aeronautical systems & test vehicles (including hypersonic vehicles) accomplished via enhanced, adaptable ground support infrastructure
- Evolve Safety-Supporting flight test regimes with minimal risk to the public, spaceport personnel or crew

6. Ballistic Missile Defense System (BMDS) flight test involving two targets and two interceptors

A ballistic missile defense system (BMDS) flight test involving two targets and two interceptors, each flying over the Pacific Ocean from different launch locations, tests the ability of the interceptors to engage and destroy the targets during all phases of flight, and illustrates the need for future spaceports to provide enhanced capabilities in terms of:

- Global Coverage—coordination between multiple spaceports to provide a sufficient number of spaceports globally to support the mission goals with common support capabilities and operational interconnection
- Standardization/Interoperability—to enable target and interceptor test launches from multiple locations, each capable of servicing and launching common vehicles rapidly and efficiently by developing common ground support equipment, systems, and infrastructure for each location
- Evolve Safety—to enable multiple launches from multiple locations and enhance the safety of maintenance, service, launch and other ground support operations
- Flexibility/Adaptability—to accommodate simultaneous launches of differently configured vehicles from individual spaceports, accomplished via enhanced, adaptable ground support infrastructure

The day in the life scenario described in this section includes a variety of missions with overlapping and concurrent operations.

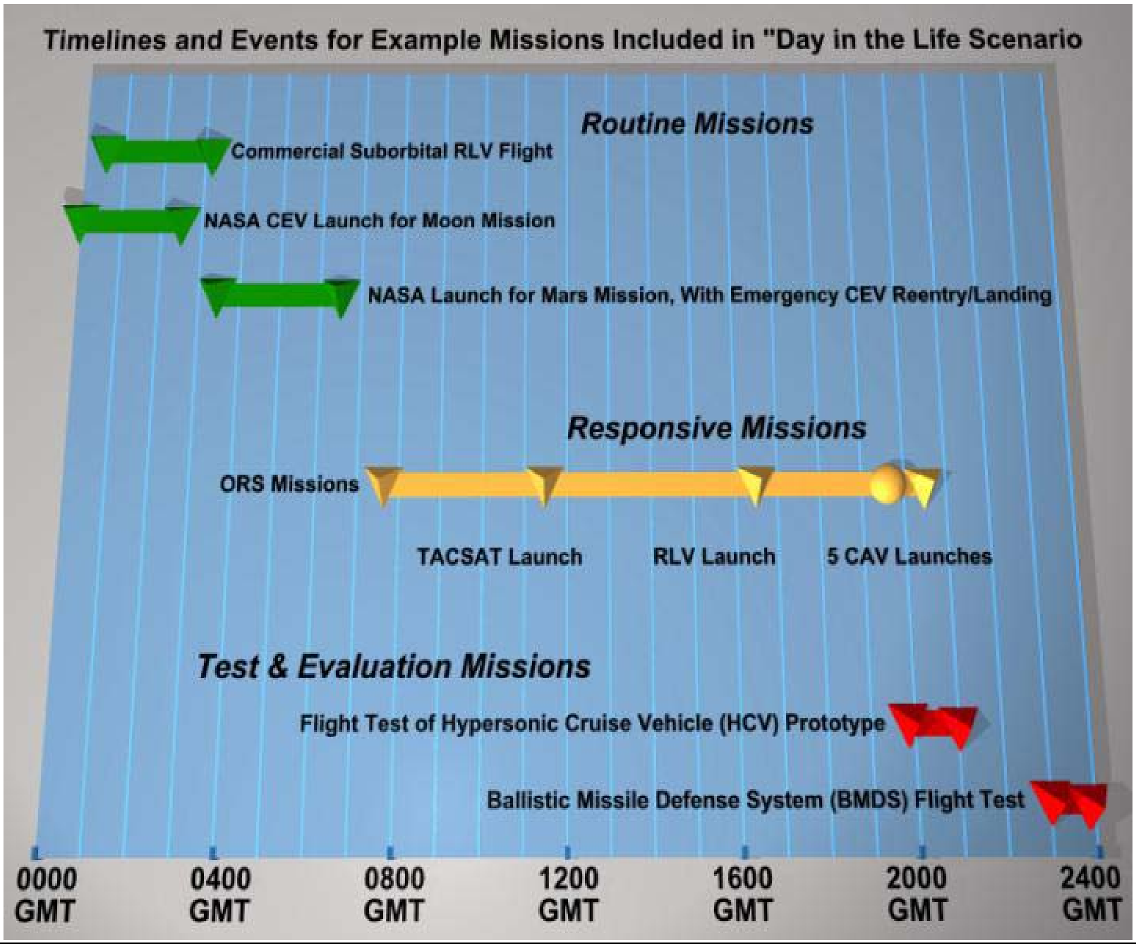


Figure 6-3 Overview of Day in the Life Scenario

The examples presented here are intended to illustrate how future spaceports with global connectivity are able to responsively support various types of concurrent missions and activities, using its inherent flexibility and adaptability to transition from one operation to another.

Based on the assumptions listed in Section 3.0 as well as the description of the technical spaceport capabilities in the Spaceport Architecture section (Section 4.0), this scenario is intended to illustrate:

- How multiple operations at an individual spaceport can be coordinated and scheduled.
- How IVHM systems can provide information and facilitate decision making with less manpower.
- How self-diagnosing/self-correcting systems can be applied
- The extent to which automated mating systems can be used to save time, improve efficiency and safety, and reduce manpower
- How airline-like operations can improve efficiency

- How smart systems within the command, control, and monitoring function can facilitate the decision making process and improve flexibility when multiple vehicles are being processed at an individual spaceport.

6.1 ROUTINE COMMERCIAL SUBORBITAL RLV FLIGHT

A routine commercial suborbital flight from Oklahoma to California highlights needs for responsive spaceport support with the capacity to support frequent and concurrent flights, standardization & interoperability to support point-to-point flights, safety approvals for overland flight, flexibility and adaptability to accommodate schedule changes, and low-cost operations to sustain and expand commercial markets.

This example illustrates how operations might be conducted early in the third era characterized by mass public space transportation. Range functions are assimilated with the spaceport functions and provided to commercial space transportation providers in a manner that makes it transparent as to whether they are range or spaceport functions. In other words, the "range" function and organization in place during the first and second eras is replaced in the third era by a "space traffic control" function and organization. Likewise, the distinction between traditional airports and spaceports of the past is now transparent with suborbital flights integrated with traditional passenger aircraft routes and infrastructure at Commercial Transportation Centers (formerly airports).

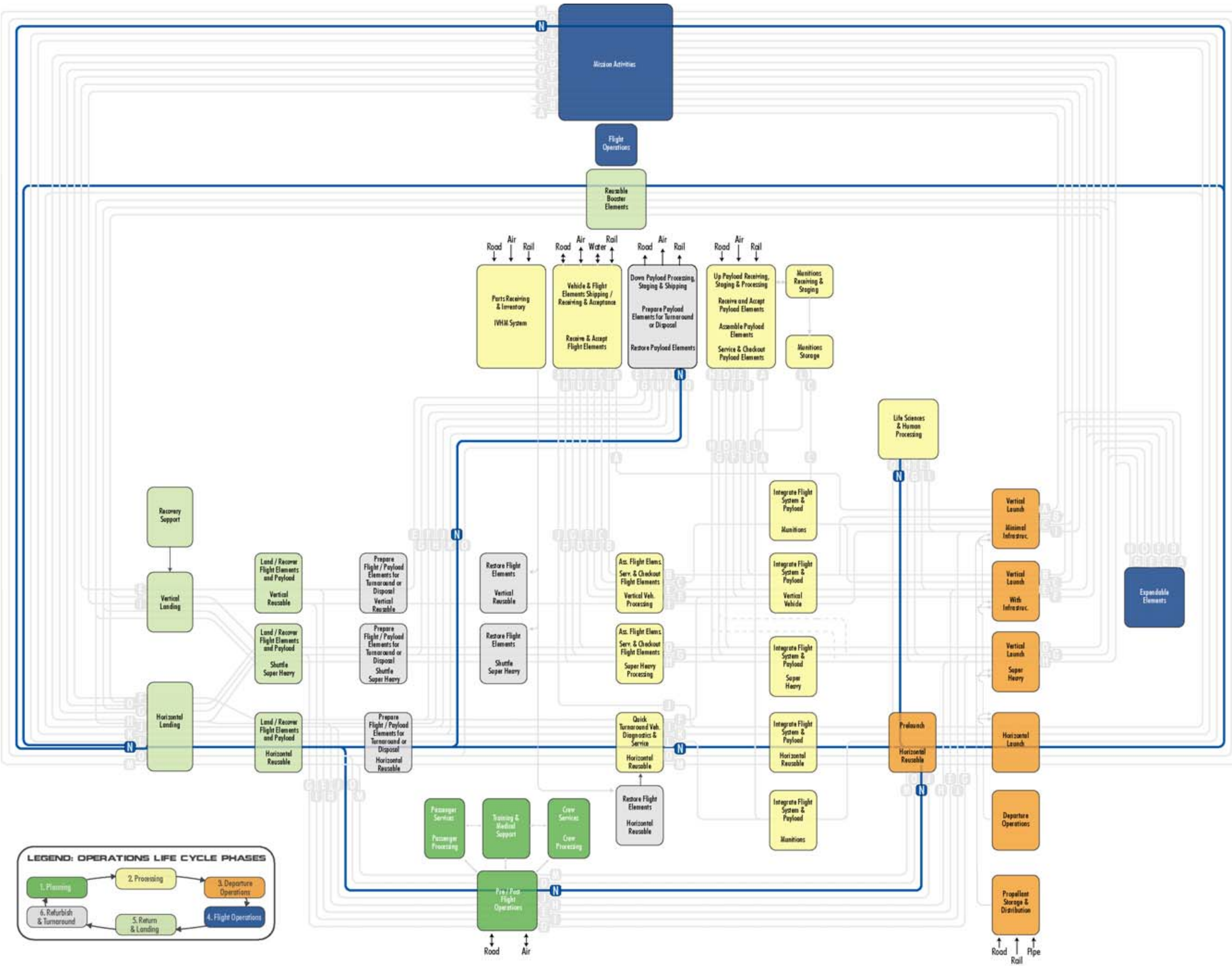
The following mission timeline provides hour-by-hour details for the mission. The spaceport base operational model with the representative operational flow model highlighted is presented in **Figure 6-4**. This is an HLHR mission using operational flow model N and the design reference mission is suborbital RLV.

Time	Mission Activity Description	Spaceport Operations
0001 GMT	Normal air and space traffic data is being monitored at various mission operations centers by government and commercial vehicle operators planning operations in the coming 24-hour period.	**Oklahoma Spaceport Operations**: Vehicle has been transported via automated tug from the hangar to the departure operations area. The CCF conducts a preflight service and condition check from the RLV IVHM system to confirm flight readiness. The automated servicing system replenishes fluid levels as indicated by CCF evaluation of vehicle specifications from the historical service database Departing passengers arrive at the transportation center where their baggage is automatically scanned and forwarded to the processing facility. Passengers proceed through pre-flight screening activities and assemble in the pre-boarding lounge in the departure operations area. Daily Flight/mission plans are filed into SATMS by vehicle operator
0050 GMT	A commercial suborbital flight from Oklahoma to California is scheduled for takeoff at 0230 GMT. This	Vehicle is readied for propellant loading by an automated mobile servicing vehicle, which automatically connects propellant lines from the in-ground fuel hydrants to the vehicle with smart, leak proof QDS. Communicating wirelessly with

	is a routinely scheduled monthly flight that's timed to give passengers dramatic views from space of the Grand Canyon, the mountainous western United States, the west coast, and the Pacific Ocean during sunset.	the CCF, the service vehicle determines the correct propellant type and quantity for the planned flight destination from data filed with the CCF
0100 GMT	Begin suborbital RLV propellant loading.	0100 GMT: Propellant loading is initiated. 0125 GMT: Propellant loading completed. QDS are disconnected and the servicing vehicle moves away.
0130 GMT	Continue pre-flight checkout processes. Passengers board the suborbital RLV at the Oklahoma Spaceport.	0130 GMT: Final preparations for passenger boarding accomplished. The human services support module is delivered and inserted into the flight vehicle payload bay. The CCF interfaces with the crew to complete the final preflight checklist 0140 GMT: Passengers board RLV through an autonomous passenger loading bridge and prepare for takeoff. Passenger loading bridge uses laser guidance to mate with vehicle 0150 GMT: The CCF initiates the departure sequence. The cabin door closes and the passenger loading bridge is automatically retracted. 0155 GMT: The RLV is pushed back from gate position by an automated GSE vehicle. 0156 GMT: Automated departure clearance is down-linked to RLV from SATMS. 0200 GMT: Engine start is initiated and the RLV taxis to runway 17R under its own power.
0230 GMT	Suborbital RLV takes off from Oklahoma for a 20-minute flight to California.	0230 GMT: RLV takeoff from Oklahoma spaceport on runway 17R. Integrated spaceport operations CCF system interfaces with SATMS and calculates flight time and schedules runway landing slot and gate position at California spaceport. 0235 GMT: The CCF initiates post takeoff checklist for ground system check and restorative activities are completed. Runway 17R is verified ready for next operation.
0240 GMT	Suborbital vehicle ascends along planned flight path and reaches apogee, beginning descent and reentry.	**California Spaceport Operations:** The CCF scans runway 30L and verifies readiness for landing. Descent flight path and landing clearances down-linked to RLV from SATMS.
0250 GMT	Suborbital RLV descends through the atmosphere, approaches the California Spaceport and lands on the	RLV lands at California Spaceport on runway 30L and taxis under its own power to arrival operations area and pre-assigned gate position. Vehicle IVHM system transmits wireless condition status to CCF, which schedules appropriate

	runway.	service and maintenance activities.
0300 GMT	California Spaceport reports mission complete to central control system.	Vehicle is scanned and verified safe for passenger offloading. The automated loading bridge moves into position, and passengers exit the vehicle. CCF executes post-flight checklist with crew, who then exit the vehicle through loading bridge.
0330 GMT		CCF initiates vehicle transfer by automated tug to hangar area for post-flight service and storage until next flight.

Figure 6-4 Routine Commercial Suborbital RLV Flight



6.2 NASA Crew Exploration Vehicle (CEV) Launch to the Moon

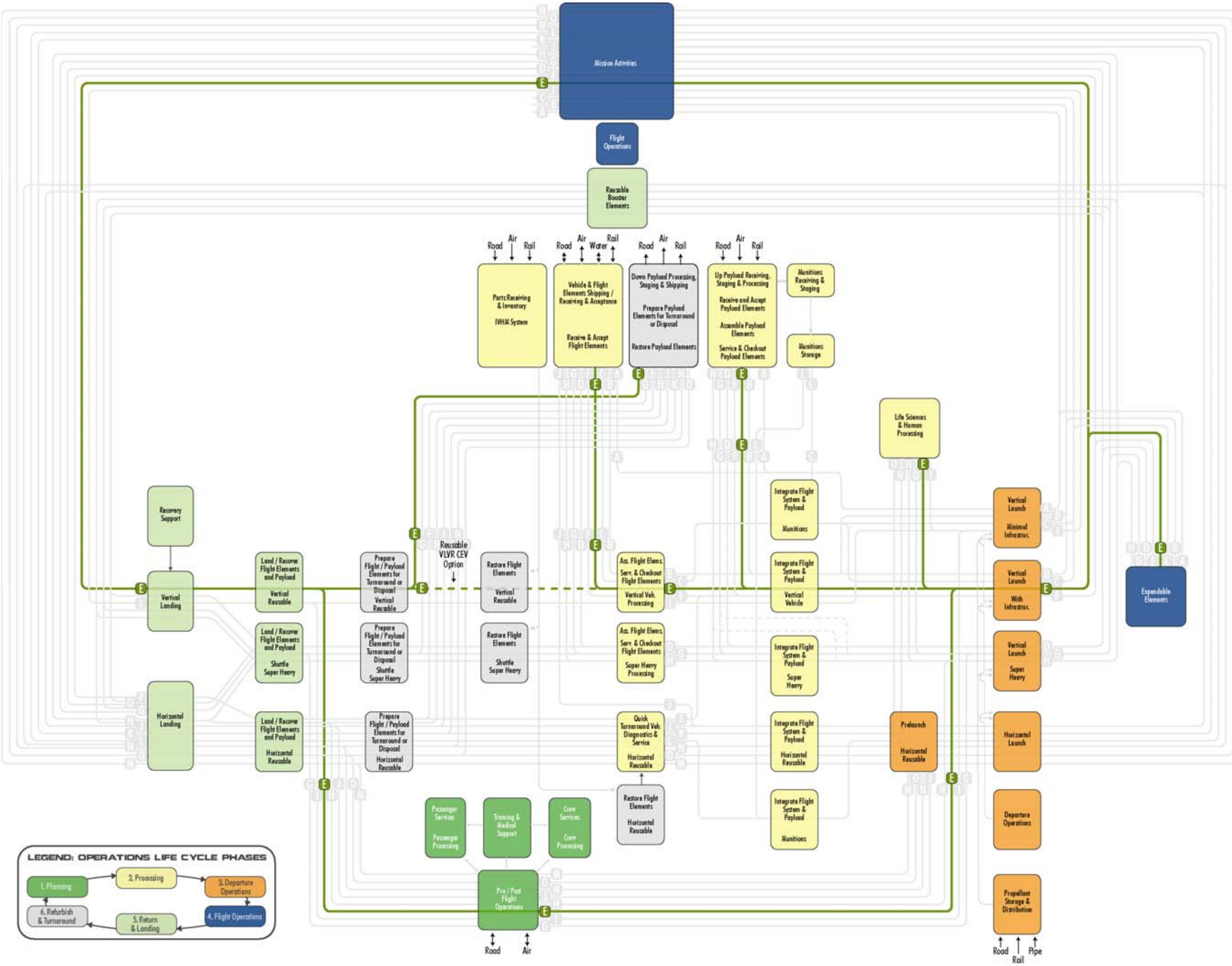
A scheduled NASA launch of a crew exploration vehicle (CEV) for a human expedition to the moon highlights the need for evolved safety to enable flights of crewed vehicles on expendable boosters, flexibility and adaptability to support operations with virtually instantaneous launch windows, concurrent operations to routinely accommodate multiple simultaneous flights, and minimized cost to enable an affordable human exploration program.

The following mission timeline provides hour-by-hour details for the mission. The spaceport base operational model with the representative operational flow model highlighted is presented in **Figure 6-5**. This is a VLVR mission using operational flow model E and the design reference mission is routine lunar exploration –crewed.

Time	Mission Activity Description	Spaceport Operations
0010 GMT	An evolved expendable launch vehicle (EELV) is scheduled for liftoff from Cape Canaveral Spaceport CCS (KSC & CCAFS), Florida at 0140. This is the fifth of six missions planned within six months.	Flight/mission plan filed into SATMS by vehicle operator. The CEV has been vertically mated to the EELV via an automated laser-guided mating mechanism in the Flight Systems Integration facility. It has been moved to the launch pad in a vertical configuration via an automated transporter and all smart umbillicals are connected at the launch site. The CCF has initiated propellant fueling, which has been completed, and cryogenic tanks are being topped off automatically and the propellant boil off recycled through a regenerative system. The CEV crew enters the vehicle through a smart crew access arm and clean room. The access arm and clean room have been retracted automatically. Crew condition is constantly monitored by the CCF via wireless transmission from personal health monitor worn by each crew member.
0100 GMT	Pre-launch checkout process begins.	The final automated launch sequence is started. Runway 9/27 is verified ready for RTLS abort. Departure clearance down-linked to automated launch control system from SATMS.
0140 GMT	EELV with CEV lifts off from CCS (KSC & CCAFS), Florida.	EELV with CEV lifts off from SLC 40A.
0145 GMT	CEV proceeds over the horizon from the launch site.	SLC 40A is inspected automatically by the pad IVHM system as well as by pad personnel and prepared for next EELV launch vehicle to arrive. Runway 9/27 is removed from emergency status and is declared ready for another operation.
0150 GMT	CEV separates and moves toward the location where it will maneuver to rendezvous and dock with other elements in orbit (delivered by previous launches) that	

	together will then be launched out of Earth orbit onto a lunar trajectory.	
0200 GMT	CEV executes rendezvous and docking maneuvers to link up with other elements in orbit.	
0215 GMT	Docking complete. Lunar exploration vehicle is configured for launch out of Earth orbit onto a lunar trajectory.	
1600 GMT	SLC 40 A ready for next launch vehicle	EELV with a payload of multiple commercial satellites is transported horizontally to the launch pad in preparation for a launch in 3 days.
1800 GMT	EELV mission at pad	Smart umbilicals are connected automatically to vehicle.
2200 GMT		Self-diagnosing sensors and vehicle configuration systems verify no damage to systems during movement to pad and that vehicle is ready for payload installation.

Figure 6-5 NASA Launch of Crewed Mission to the Moon



6.3 NASA Shuttle-Derived Super Heavy Lift Vehicle for Mission to Mars

A scheduled NASA launch of Shuttle-derived super heavy lift vehicle to support crewed mission to Mars highlights the need for concurrent operations to routinely accommodate multiple simultaneous flights, ability to adjust payloads near T-0, and minimized cost to enable an affordable human exploration program.

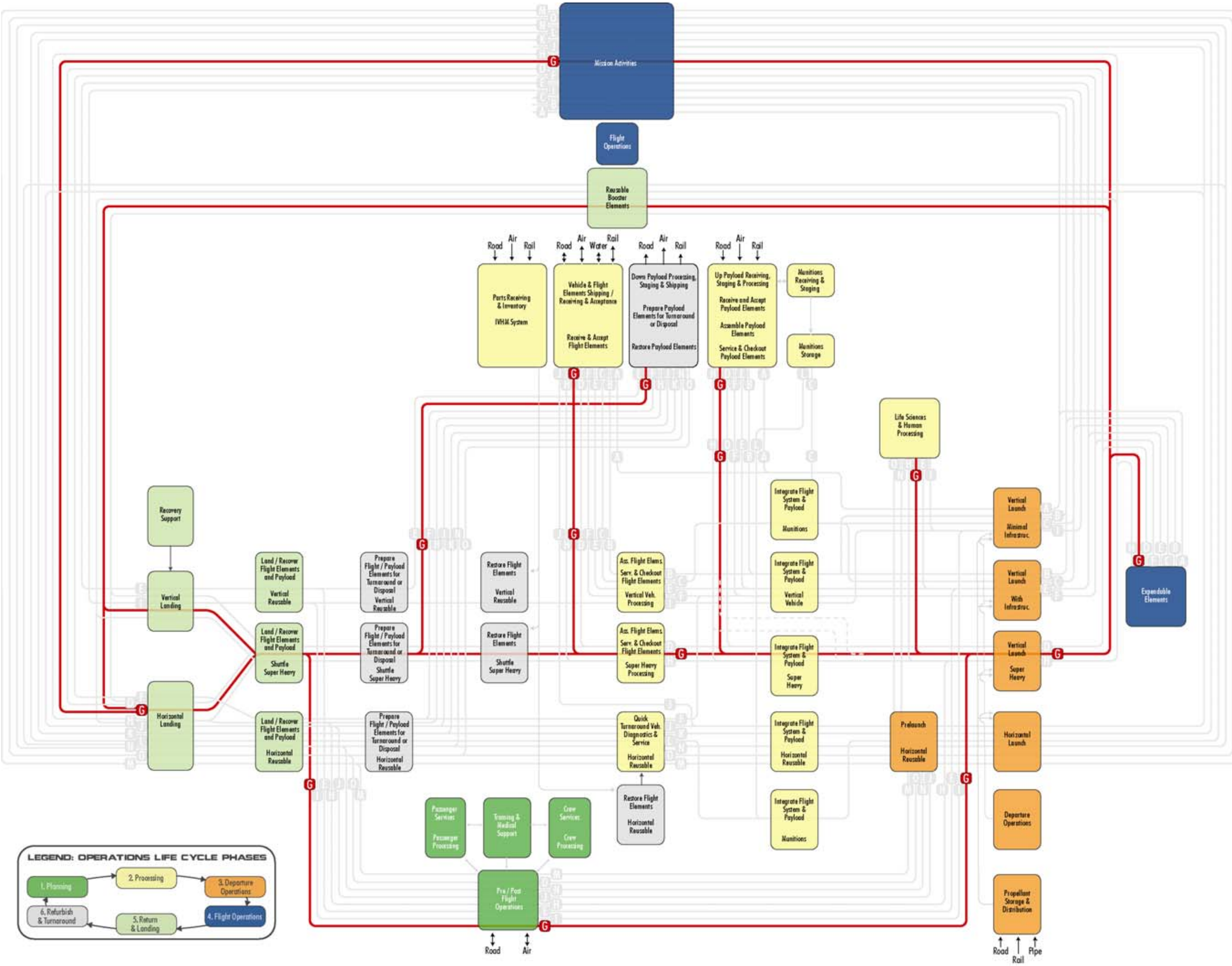
The following mission timeline provides hour-by-hour details for the mission. The spaceport base operational model with the representative operational flow model highlighted is presented in **Figure 6-6**. This is a VLHR mission using operational flow model H and the design reference mission is Mars exploration –crewed.

Time	Mission Activity Description	Spaceport Operations
0440 GMT	A Shuttle-derived super heavy lift launch vehicle (with a reusable first stage) is scheduled for liftoff from CCS (KSC & CCAFS) at 0610. This is the fourth of six missions that will be launched over a six-month span to assemble large spacecraft in orbit and conduct a crewed mission to Mars.	Flight/mission plan filed into SATMS by vehicle operator. The CEV and payload have been mated to the launch vehicle via an automated laser mating mechanism in the Vertical Assembly Building. It has been moved to the launch pad via an automated transporter and all smart umbillicals are connected. Propellant fueling has been completed and cryogenic tanks are being topped off automatically and the boil off recycled through a regenerative system. The crew enters the CEV through a smart crew access arm and clean room. The access arm and clean room have been retracted automatically.
0435-0455 GMT	As noted in the current space weather forecast, the effects of a recent solar flare are reaching the region between the Earth and Mars, where a previously launched CEV is already in transit. The solar flare disrupts communications with the CEV in transit. When communication is re-established, the crew reports that one of the redundant CEV telemetry transmitters has been damaged by the storm and requests a replacement unit be sent with the next crew.	The autonomous configuration monitoring and control system at the launch site identifies the required part and has it available. A ground operator identified by the personnel locator system drives the spare telemetry transmitter to the CEV on the launch pad, where the on-board crew stows it in a locker that has been reserved for contingencies. Standard prelaunch checkout continues during this process.

0500 GMT		The crew access arm and clean room are retracted automatically.
0510 GMT	Pre-launch checkout process begins.	The final automated launch sequence is started. Runway 15/33 is verified ready for RTLS abort and Runway 9/27 is verified ready for fly back booster. Departure clearance down-linked to automated launch control sequence from SATMS.
0610 GMT	NASA Shuttle-derived super heavy lift launch vehicle lifts off from CCS (KSC & CCAFS)	Vehicle launched from SLC 39B.
0611 GMT	Reusable first stage separates and begins flight back toward runway near launch location.	Runway 27 identified as return runway for reusable first stage based on automated flight glide path system.
0615 GMT	Crew exploration vehicle (CEV) and payload proceed over the horizon from the launch site.	Reusable first stage lands on Runway 27 and is transported by automated tug to turn around area.
0630 GMT	CEV and payload separate in orbit and begin maneuvers toward rendezvous and docking with other elements in space.	The CCF scans Runways 15/33 and 9/27. Debris is identified on 9/27 and cleared by the automated debris removal system. Both runways are returned to operational status.
0700 GMT	CEV and payload reach the proximity of the other elements in orbit and begin rendezvous and docking maneuvers.	
0710 GMT	CEV experiences an anomaly that results in the loss of two of its three redundant power busses during rendezvous operations. After attempting to reset the circuit breakers, the CEV crew declares an emergency and begins preparations for reentry and landing.	Emergency return from orbit systems alerts potential landing sites of emergency while the advanced modeling systems determines the optimal and other return trajectories. CEV up-links reentry and landing data to SATMS, which returns an automated clearance for emergency operation – airspace is appropriately restricted surrounding the space transition corridor (STC).
0712 GMT	CEV maneuvers away from other spacecraft and begins emergency reentry procedures.	Automated scheduling function calculates a spaceport landing support plan based on the calculated reentry and flight profile and schedules the emergency use of the intended emergency-landing site.
0718 GMT	CEV begins reentry.	
0740 GMT	CEV lands safely and recovery operations begin.	CEV Lands on designated runway at Vandenberg AFB. An automated tug directed by the CCF transfers the CEV to the post-recovery processing area where a mobile scanner checks the CEV and conducts safing operations.

0755 GMT		CEV is tugged to the flight recovery facility where the automated configuration management system and the IVHM system have interfaced and determined cause of power buss loss. Parts are located and automated installation is scheduled by the automated scheduling system.

Figure 6-6 NASA Launch of Crewed Mission to Mars



6.4 Operationally Responsive Space (ORS) Missions

Operationally Responsive Space (ORS) missions to launch prompt global strikes highlight needs for responsive spaceport support with the capacity to support frequent and concurrent flights, standardization & interoperability to support launches from multiple locations, safety approvals for responsive flights, flexibility and adaptability to accommodate frequent missions from multiple locations, and low-cost operations.

The following mission timeline provides hour-by-hour details for the mission. The spaceport base operational model with the representative operational flow models highlighted is presented in **Figure 6-7**. This is a HLHR mission using operational flow model L and the design reference mission prompt global strike.

Time	Mission Activity Description	Spaceport Operations
0600 GMT		CCF conducts daily status verification of launch readiness for ORS vehicles throughout the global spaceport network system based on verification of on-board IVHM system in conjunction with overall ORS mission system. Fueled and ready to launch vehicles are on ready alert at Vandenberg SLC 7 and 8, and CCS (KSC & CCAFS) SLC 20 and 21
0646 GMT	U.S. early warning satellites detect a launch of an expendable rocket of unknown type from a nation currently antagonistic toward the United States. The trajectory appears to be toward high-inclination low Earth orbit.	
0732 – 0750 GMT	Ground controllers lose contact with a U.S. commercial imaging satellite. Debris is detected by space surveillance sensors not related to the range, emanating from the imaging satellite's anticipated orbital position.	
0815 – 0830 GMT	The DoD mission operation center that controls ORS missions submits a high-priority schedule request through the automated range scheduling system to delay other scheduled range activities to initiate planning for two ORS missions later in the day. Both are to be	**At Vandenberg:** 0845 GMT: In response to command for an ORS mission, micro satellite is installed on an ELV using laser guided installation system. Smart connectors mate automatically between satellite and vehicle and self-checks are performed. 0930 GMT: Autonomous transporter moves vehicle with payload to pad.

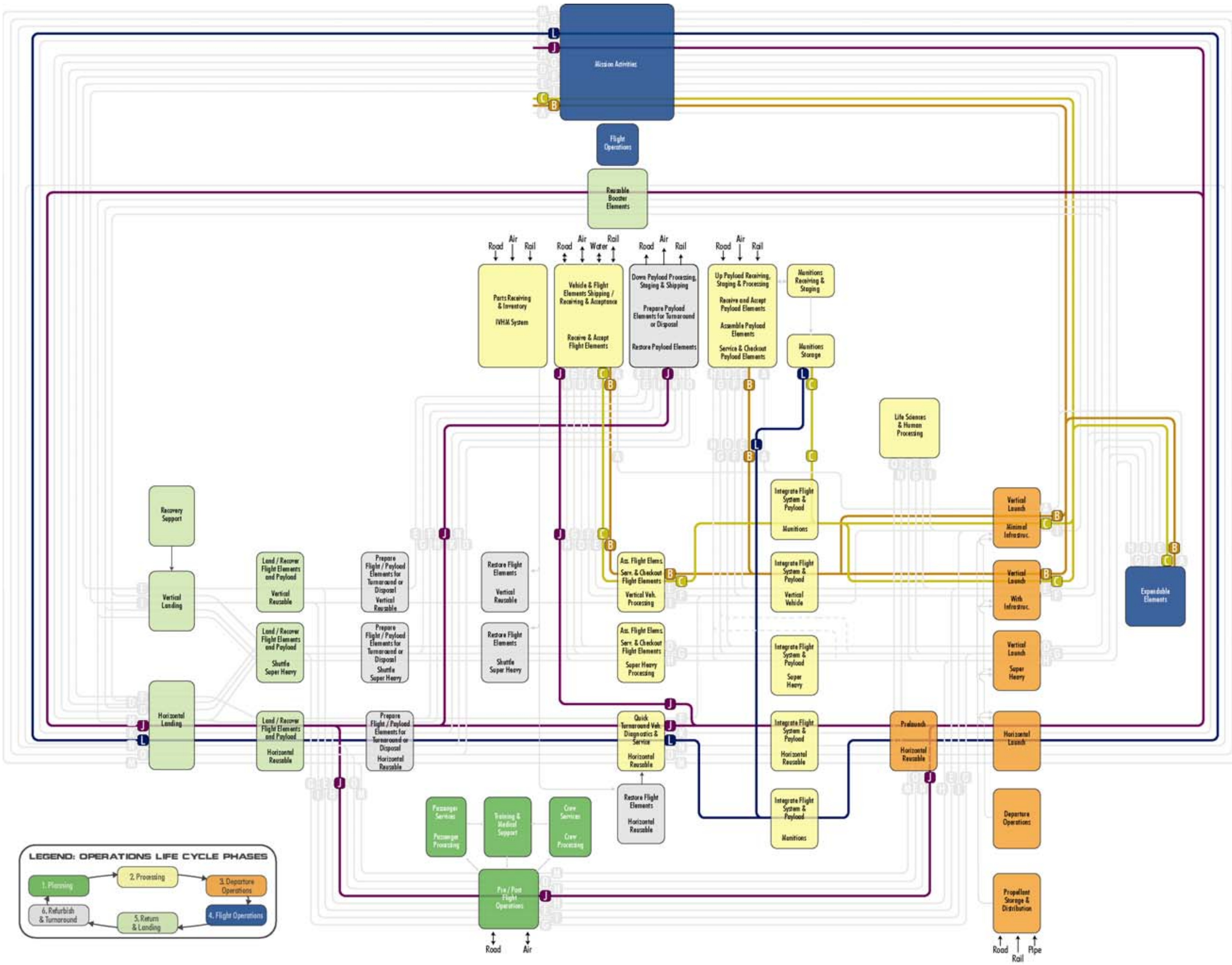
	conducted in response to the unanticipated foreign launch because DoD suspects it may have been carrying an anti-satellite weapon that attacked the commercial imaging satellite to mask preparations for regional aggression. DoD orders a rapid-response ORS mission from Vandenberg AFB to launch an inspection micro satellite at 1147 GMT so it can go into an orbit that will enable it to maneuver and rendezvous with the remains of the commercial imaging satellite to inspect it for evidence of attack. DoD also orders preparations for an unpiloted reusable ORS vehicle at CCS (KSC & CCAFS) to be prepared for launch a few hours later.	1015 GMT: Smart umbilicals are connected and fueling operation is started automatically. 1100 GMT: Guidance data is loaded into ORS guidance system remotely. Internal systems verify ready for launch. **At** CCS (KSC & CCAFS): 0845 GMT: In response to command for an ORS mission, an unmanned ORS RLV is towed from hanger to prelaunch area. Prelaunch checks are initiated. **1030 GMT: Vehicle is fueled by automatic fueling system and is standing by for launch.**
1147 GMT	ORS launch from Vandenberg AFB, timed to coincide with the passage of the orbital plane of the non-functioning commercial imaging satellite over the launch location.	ELV is launched from Vandenberg SLC 6
1349 GMT	ORS mission to inspect satellite is now complete	
1510 GMT	An ORS launch from CCS (KSC & CCAFS) is ordered for 1620 GMT.	ORS RLV on standby at CCS (KSC & CCAFS)is given launch time of 1620 and guidance information is downloaded to on-board computer automatically.
1550 GMT	Final checkout of ORS RLV begins.	ORS RLV taxis under its own power to runway 13 and does engine run up and final preflight checks.
1620 GMT	Takeoff of reusable launch vehicle from CCS (KSC & CCAFS).	ORS RLV takes off from runway 13 at CCS (KSC & CCAFS)
1624 GMT	Flight vehicle proceeds over the horizon from the launch site.	Runway 13/31 inspected with automated inspection system and determined to be ready for continued use.
1705 GMT	RLV passes over the foreign launch site and conducts its reconnaissance mission.	

1750 GMT	RLV reenters and flies toward the planned landing site.	
1755 GMT	RLV lands and DoD ORS mission control center reports mission complete.	RLV lands on Runway 31 and rolls out. It is inspected automatically, then towed to hangar area for preparation to go back on active status.
1845 GMT	Based on results of the inspection and reconnaissance missions, DoD determines that the foreign launch did carry the ASAT weapon that destroyed the commercial imaging satellite. Additional intelligence reporting in the mean time has concluded that there are three more ASATs being prepared for launch in the antagonistic country. The President orders a prompt global strike mission to destroy the ASAT launchers before they can attack other U.S. satellites.	
1900-1930 GMT	Preparations orders are issued to conduct simultaneous ORS launches of five vehicles from two land-based locations in the continental United States and from one airborne platform flying off the west coast. Common Aero Vehicles (CAVs) with munitions are loaded onto two ground-based launch vehicles at one launch site, and onto another ground-based vehicle at another. A CAV with a UAV for battle damage assessment is loaded onto the other launch vehicle at the second launch site.	**At Vandenberg:** EELVs on SLC 7 and 8 have CAVs loaded with munitions automatically attached and IVHM systems verify each is ready for launch. **At CCS (KSC & CCAFS)**: A launch vehicle on SLC 20 has a CAV containing a UAV automatically attached and IVHM system verifies vehicle is ready for launch. A launch vehicle on SLC 21 has a CAV with munitions automatically attached and IVHM system verifies vehicle is ready for launch. **At a undisclosed DoD base:** An aircraft containing a CAV is on standby on runway 17.

1900-1930 GMT	site. The aircraft carrying the fifth CAV (already loaded with munitions) takes off from its alert position and establishes its racetrack pattern over the Pacific Ocean, awaiting specific targeting data and the launch order.	
1930 GMT	Targeting data is uploaded to each CAV and the launch order is issued. All five launch vehicles begin their flights at the same time.	All 4 launches are completed while aircraft takes off on runway 17/35.
1933-1940 GMT	One of the launch vehicles flying over the ocean from the eastern launch site malfunctions and its autonomous flight termination system destroys the launch vehicle, the CAV, and its munitions payload. The other four launch vehicles proceed over the horizon from their initial launch locations. The CAVs separate from their launch vehicles and begin traveling through space along ballistic trajectories toward the target area.	
1942 GMT	DoD issues a re-targeting command for one of the CAVs carrying munitions, and now flying along a ballistic trajectory through space.	
1944 GMT	All four CAVs begin reentry.	
1950 GMT	All four CAVs complete reentry and begin atmospheric glide maneuvers toward their designated targets.	At Vandenberg and CCS (KSC & CCAFS), preparations are made to schedule vehicles to be readied for future ORS missions.

1955 GMT	The CAV carrying the UAV reaches its dispensing altitude and speed, and deploys the UAV to begin its ISR mission to collect battle damage assessment data.	
2002 GMT	The three CAVs carrying munitions reach their dispensing altitude and speed, and deploy their munitions payloads.	
2003 GMT	Munitions explode on their targets. UAV collects and transmits real-time video.	
2006 GMT	CAV aeroshells autonomously destruct.	
2010 GMT	CAV mission complete.	

Figure 6-7 Operationally Responsive Space (ORS) Prompt Global Strike (PGS) Missions



6.5 Flight Test of a New Prototype DoD Hypersonic Cruise Vehicle (HCV)

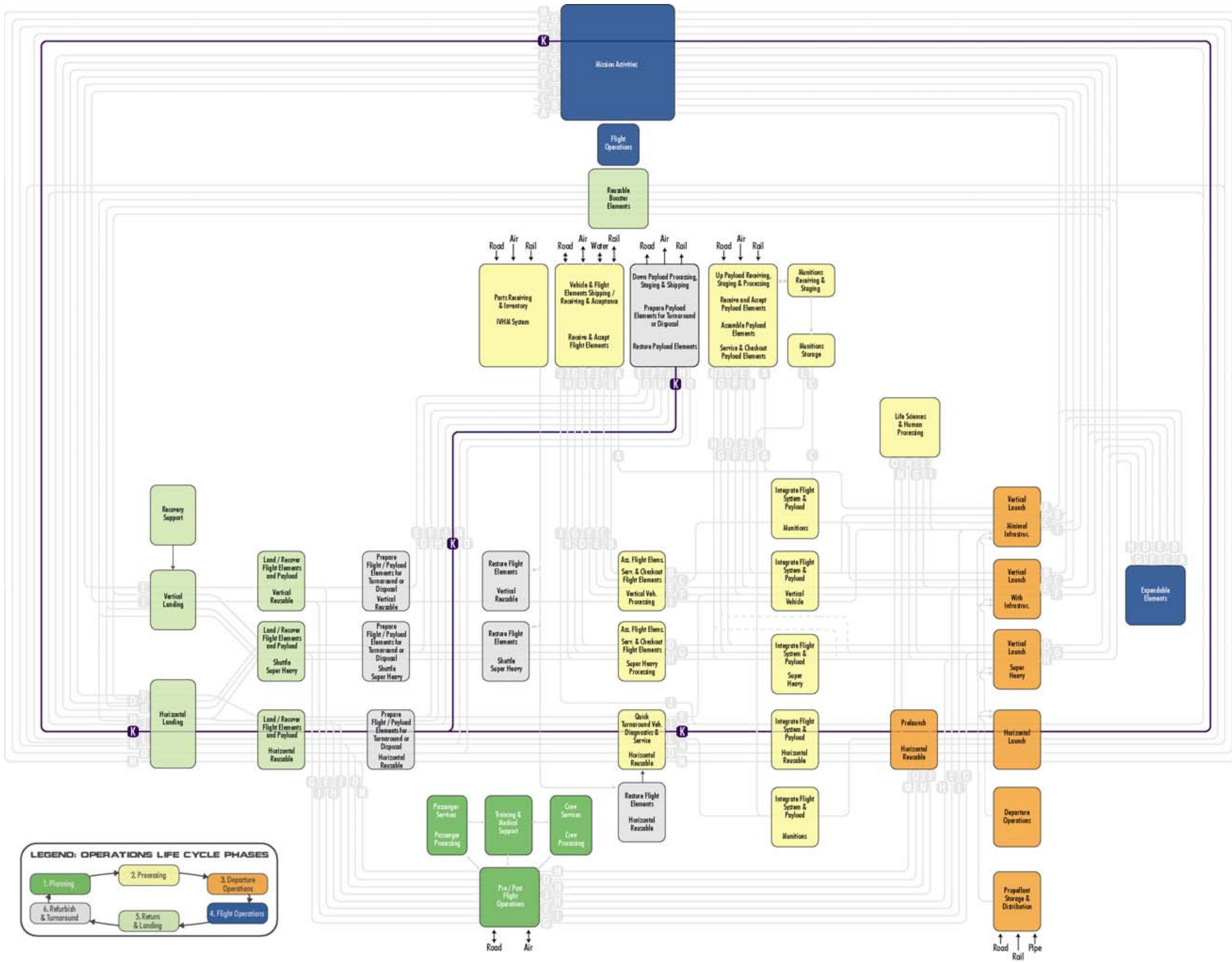
Flight test & evaluation of a new prototype DoD hypersonic cruise vehicle highlights needs for spaceport responsiveness to support multiple concurrent aeronautical flight tests per day, standardization and interoperability to enable point-to-point flight operations.

The following mission timeline provides hour-by-hour details for the mission. The spaceport base operational model with the representative operational flow model highlighted is presented in **Figure 6-8**. This is an HLHR mission using operational flow model K and the design reference mission is hypersonic flight T & E.

Time	Mission Activity Description	Spaceport Operations
0815 GMT	Test flight of a new prototype DoD hypersonic cruise vehicle (HCV) had originally been scheduled for 1630 GMT has been re-scheduled for 1945 GMT takeoff to avoid potential interference with multiple concurrent operational CAV launches.	California DoD test site notified of delay of flight test from 1630 to 1945 due to CAV launches. An automated scheduling system recalculates timing of preparation and launch and prints revised test documents and notifies mission personnel.
1730 GMT		The CCF initiates automated towing of the HCV to pre-launch area where the vehicle is positioned for automated fueling,
1800 GMT		Robotic mobile GSE vehicle (RMGV) performs automated scan of the exterior of the vehicle and artificial intelligence system on-board RMGV monitors and evaluates internal HCV systems.
1940 GMT	Test flight of a new prototype DoD hypersonic cruise vehicle (HCV) had originally been scheduled for 1945 GMT has been re-scheduled for 2005 GMT takeoff to avoid potential interference with multiple concurrent operational CAV launches. CAVs are now well over the horizon from the continental U.S., conducting their operational missions.	California DoD test site is notified of additional delay to launch time from 1945 to 2005. Automatic scheduling systems recalculates launch timetable and electronically transmits revisions.
	HCV mission operations center begins running a simulation program to be integrated with the flight test	

	of the actual HCV hardware. This particular simulation program adds elements of training for HCV operators by imposing a virtual hostile threat environment and simulated reconnaissance mission objectives on the HCV flight test.	
1955-2005 GMT	DoD HCV undergoes its final pre-flight checkouts on the runway.	HCV tugged to runway 27R at California DOD test site and automated preflight tests are performed. Engines are started and run up is completed.
2005 GMT	Takeoff of DoD HCV from a DoD site inland in California.	Take off of HCV on runway 27R
2010 GMT	HCV proceeds over the horizon from the takeoff site.	Automated runway scanning system verifies runway 9L/27R ready for return of HCV.
2015-2045 GMT	HCV accelerates to hypersonic speeds over Pacific Ocean, then decelerates and turns to fly the simulated reconnaissance mission profile and avoid simulated threats based on operator inputs. Following completion of this segment of the mission, the HCV proceeds back toward the landing site.	
2045-2055 GMT	HCV appears over the horizon and approaches the landing site. HCV successfully lands, rolls out, and completes its flight test mission.	Landing of HCV on runway 9L at California DoD test site and rolls out to a stop. RMGV scans HCV with a variety of sensors and determines HCV is in a safe condition.
2100 GMT		HCV is towed to hanger area for post flight inspection and download of data from on-board sensors and flight recorders and autonomous IVHM system

Figure 6-8 Flight Test & Evaluation Mission for New Prototype DoD HCV



6.6 BALLISTIC MISSILE DEFENSE SYSTEM (BMDS) FLIGHT TEST

Two-on-two ballistic missile defense system (BMDS) flight test involving two targets and two interceptors, each launched from a different location highlights needed standardization and interoperability to enable target and interceptor launches from multiple locations, evolved safety approval processes to enable complex intercept tests, and flexibility and adaptability to accommodate frequent flights and schedule changes.

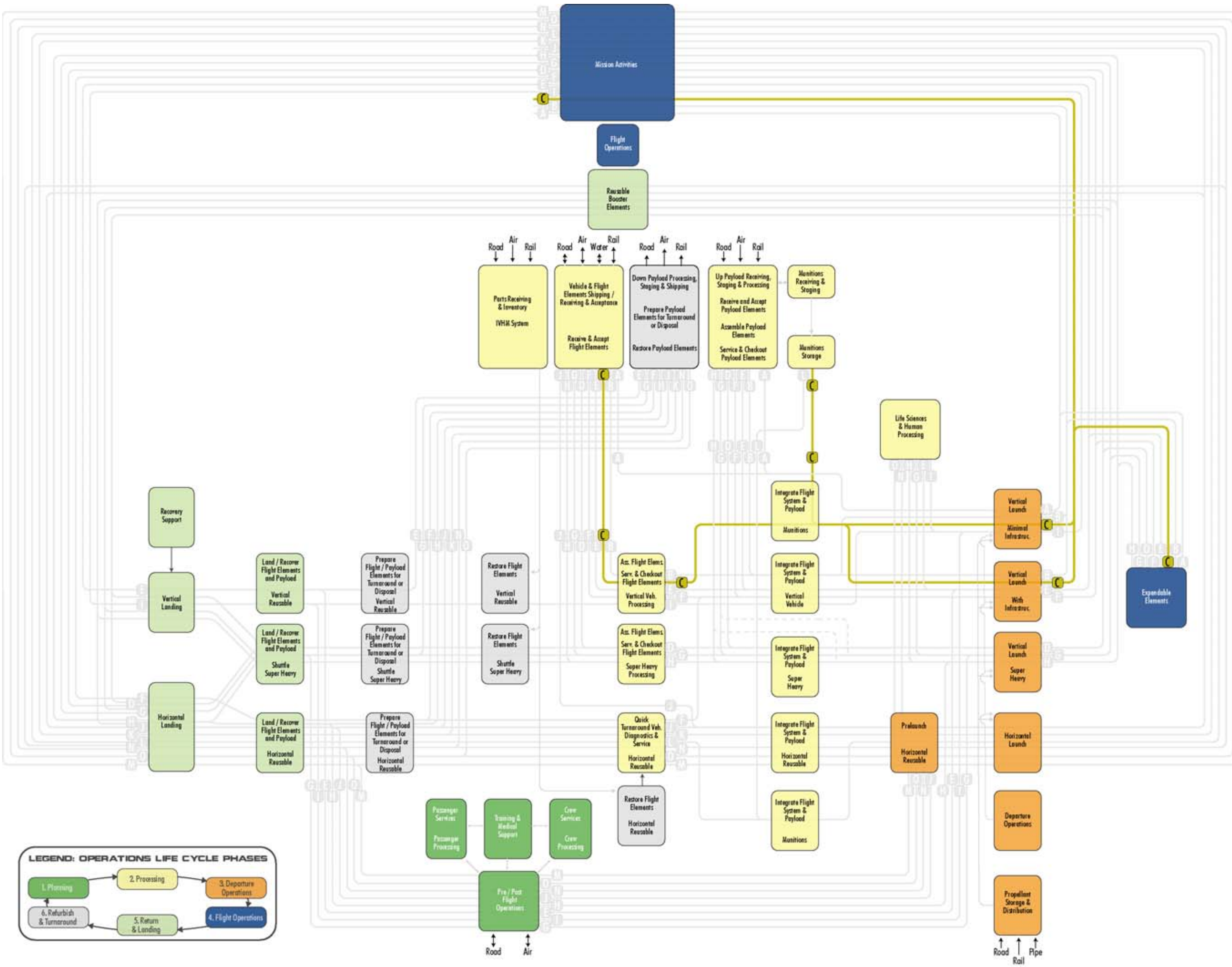
The following mission timeline provides hour-by-hour details for the mission. The spaceport base operational model with the representative operational flow model highlighted is presented in **Figure 6-9**. This operational flow model would be applicable to all three space centers in this example. This is a VLE mission using operational flow model B and the design reference mission is ICBM flight T & E.

Time	Mission Activity Description	Spaceport Operations
0400 GMT	As part of today's flight test target vehicles will be launched simultaneously from the Reagan Test Site at Kwajalein Atoll in the Marshall Islands, and from the Kodiak Launch Center in Alaska. Both will proceed toward the west coast of the United States. Two interceptors will be launched from Vandenberg AFB, CA to engage the targets.	The target launch vehicle at Kodiak Launch Center has been transported vertically to SLC 4 and is undergoing automated prelaunch electrical tests. The target launch vehicle at the Reagan Test Site has been transported vertically to SLC 1 and is nearly complete with a self-test of the guidance computer that was installed yesterday as the result of a predicted anomaly discovered by an advanced algorithm in the self-diagnostic system. The two interceptor vehicles are at SLC 4A and 5A in the midst of a 24-hour stand-by readiness check. They are fully fueled and in a go for launch condition as they would be in their operational mode.
1200 GMT		The readiness check of the two interceptor vehicles is completed successfully. The launch team is on station and in the process of running advanced failure mode tests to evaluate their responses with armed and fueled vehicles as directed by the autonomous knowledge-based training system.
1600 GMT		Both target vehicles have completed electrical testing and are ready for propellant loading.
1800 GMT		Commence automated propellant loading of the two target vehicles.
1805 GMT		Imbedded sensor in the oxidizer loading GSE detects a temperature increase in one of the servicing lines to the vehicle on SLC 4 at the Kodiak Launch Center and directs a self-healing insulation repair. Temperature returns to nominal range and fueling continues without interruption.

2100 GMT		Target vehicle fueling completed successfully. Count down to launch continues on target vehicles.
2300 GMT	Spare autonomous airborne mobile range asset arrives on station over southern Pacific Ocean after 15 hours in transit, where it will be used to support ballistic missile defense tests.	
2310 GMT	BMDS mission operations center begins running a simulation program as part of a war game exercise to depict and provide context for the threat scenario that will be addressed by the two-on-two BMDS flight test. The flight test will provide a hardware-in-the-loop element for this war game, which will also include virtual and simulated elements as part of the integrated test and training exercise being conducted today.	
2315 GMT	A two-on-two BMDS intercept test scenario is scheduled to begin at 2335 GMT. Target vehicles will be launched simultaneously from the Reagan Test Site at Kwajalein Atoll in the Marshall Islands, and from the Kodiak Launch Center in Alaska. Both will proceed toward the west coast of the United States. Two interceptors will be launched from Vandenberg AFB, CA to engage the targets.	Interceptor vehicles at Vandenberg are at alert status ready for a launch command.
2330 GMT		Target vehicles proceed into final automated launch sequences at Kodiak Launch Center and Reagan Test Site.
2335 GMT	Target vehicles take off from Alaska and Kwajalein for a 16-minute flight toward California.	Simultaneous launch of target vehicle from Kodiak Launch Center SLC 4 and from Reagan Test Site SLC 1
2340	Two interceptor vehicles are	Simultaneous launch of interceptor vehicles from

GMT	launched from Vandenberg. As part of the test, virtual decoy data and other background data simulating a salvo of ten threat missiles are inserted by command uplink into the data stream that feeds the interceptor vehicle's guidance and targeting systems.	Vandenberg, SLC 4A and SLC 5A
2340 GMT	Interceptors approach and engage the target vehicles.	
2345 GMT		SLC 4 at the Kodiak Launch Center and SLC 1 at the Reagan Test Site are inspected automatically by the pad IVHM system as well as by pad personnel. Several maintenance items are identified and scheduled by the automated scheduling system.
2350 GMT	BMDS mission complete reported to central control system.	SLC 4A and SLC 5A are inspected automatically by the pad IVHM system as well as by pad personnel and prepared for next test launch vehicles to be transported to the pads.

Figure 6-9 Ballistic Missile Defense System Flight Test



7.0 ENABLING TECHNOLOGIES

This section describes the enabling technologies that will be necessary to develop the future spaceport architecture and operations described in this CONOPS. The development of this CONOPS included an extensive review of the ASTWG Report findings and results. Conclusions presented here reflect concurrence with and adoption of ASTWG findings based on research conducted, other studies and documents reviewed, and independent interviews with subject matter experts. The ASTWG enabling technology roadmaps were used throughout the CONOPS to illustrate the five technology focus areas based on their verified relevance and applicability.

Included are a variety of approaches that address the technical challenges that stand in the way of achieving the necessary capabilities for each of the spaceport functional areas.

The five technology focus areas are:

- Advanced Servicing
- Command, Control, and Monitoring
- Inspection and System Verification
- Transportation, Handling, and Assembly
- Planning, Documentation, Analysis, and Learning

The remainder of this section describes opportunities and recommendations regarding development and demonstration activities that should be pursued to address each of these technology focus areas and enable the future spaceport capabilities envisioned in this CONOPS. Included in each of the five technology focus areas is the enabling technology roadmap developed in the ASTWG report presenting the recommended time-phased approach to pursuing that technology focus area.

Many of the technology focus areas listed above and depicted on the enabling technology roadmaps overlap with many other areas of applicability besides spaceports. This overlap leads to possibilities for synergy and collaboration to advocate, develop, and demonstrate technologies with a variety of applications, both on and off spaceports. For example, robotics, mechanical/optical positioning systems, the ability to self-test and self-heal, autonomous configuration management, and the broad field of expert systems/artificial intelligence, and knowledge based tools.

Preliminary performance parameters were identified to set goals for improving spaceport capabilities. The table below outlines these parameters.

	Performance Parameters		
Spaceport Functional Area	**Current**	**1st Era**	**2nd Era**
Flight Element Operations			
Receive and accept	Days to weeks	Hours	Minutes to hours
Assemble	Weeks to months	1 day	Hours--not on critical path
Service and Checkout	Weeks to months	1 day	Hours
Payload Element Operations			
Receive and accept	1 week	1 day	Hours
Assemble	Months	Days	Not required
Service and Checkout	Days to months	Hours to days	Within hours of flight
Integrated Operations			
Flight/Payload Integration	Days to weeks	Hours	Minutes to hours
Departure	Weeks to days	Hours	Minutes/on-demand
Flight and Ground Traffic Control and Safety Operations – Flights	1 per 2 days	1 per day	Multiple flights per hour
Enabling Operations			
Configure GSE for next operation	Weeks	Hours	Minutes
Turnaround/process/launch	Months	Weeks	4 hours
Ground-based equipment turnaround	Months	Weeks	< 2 days
Reconfigure to a different operation	Months	12 hours	8 hours
Reconfigure for a new/modified vehicle	Years	Months	Within 30 days
Landing/recovery operations	Days	1 Hour	Minutes
Operational cost		25% reduction	50% reduction
Safety-Accident Rate	47,000/1 million		57/1 million

Source: ASTWG Baseline Report/FIRST Needs Assessment/ZHA

7.1 TECHNOLOGY FOCUS AREAS

7.1.1 Advanced Servicing

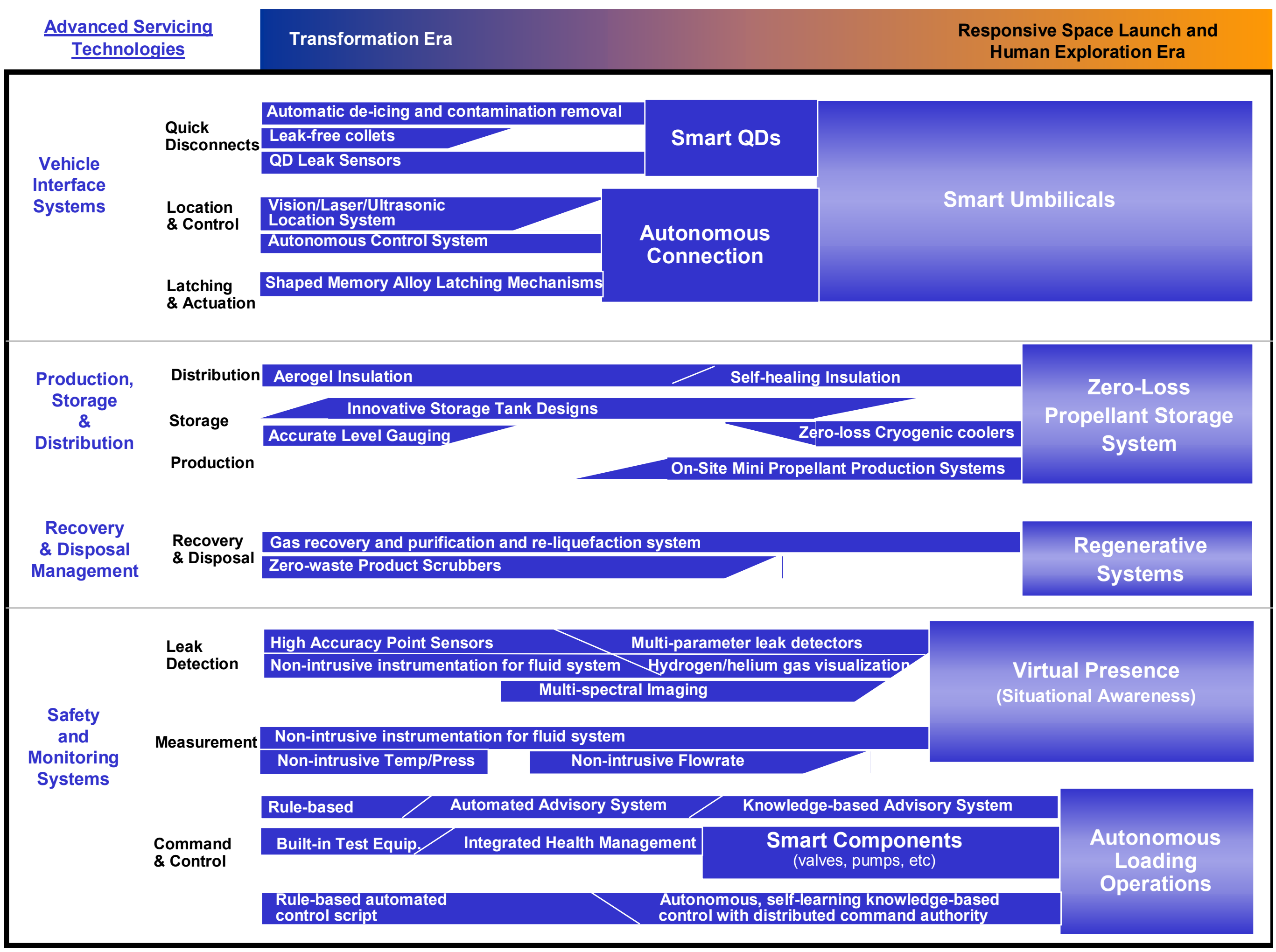
Technology development and demonstration activities to enable safe, rapid, efficient and economical servicing capabilities into future spaceport and space vehicle systems will:

- Decrease the amount of spaceport servicing that is on the critical path.
- Improve the servicing process.
- Reduce workforce exposure to hazardous materials.

This enabling technology focus area could be pursued in the first era by improving quick disconnects by developing leak free collets, automatic de-icing and QD leak sensors. Second era evolution would be to smart QDs. Similarly, first era advancements in other areas of vehicle interface connections would include sophisticated alignment and autonomous control systems as well as improved latching systems that would develop toward a second era goal of autonomous connection and disconnection. Ultimately, the technology would lead to the development of smart umbilicals for all vehicle connections.

In parallel, first era technology efforts to improve propellant and other fluid production, storage and distribution would include improvements in cryogenic piping insulation and storage tank design and remote repair capabilities could enable evolution in the second era to technologies for self-healing insulation. There should also be a first era effort to improve recovery and disposal management. All of these technologies could be combined by the start of the third era to produce systems with regenerative, zero loss propellant transfer and storage systems.

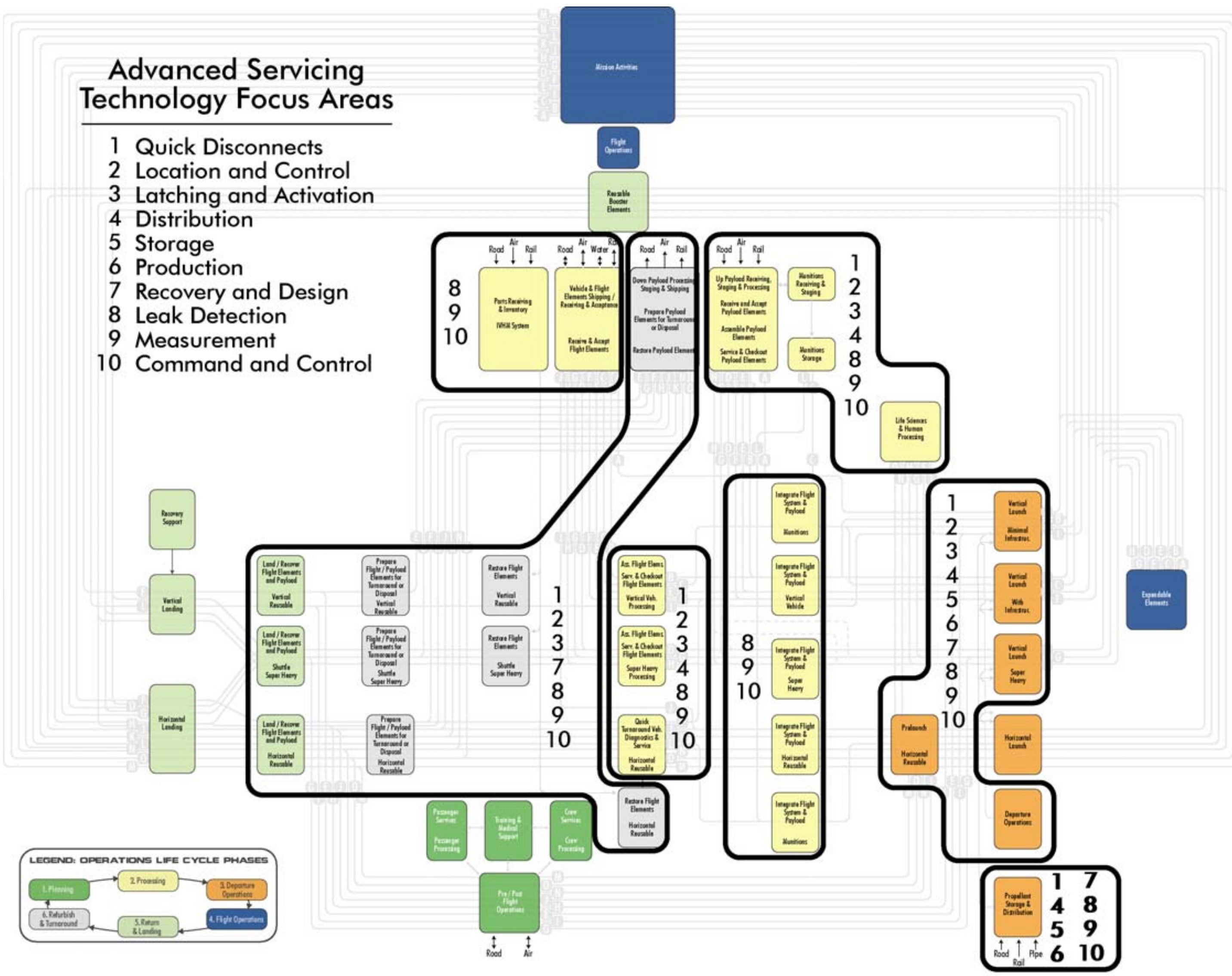
In conjunction with the above, technologies should be developed to improve safety and overall process control by improving leak detection and measurement through the use of nonintrusive sensors. Better command and control of vehicle servicing could be achieved with built-in test equipment and the development of rule-based systems. By the start of the third era this would lead to knowledge-based control systems and smart components allowing autonomous loading operations. The Technology Roadmap for Advanced Servicing is shown in **Figure 7-1**.



Source: ASTWG Baseline Report

Figure 7-1 Advanced Servicing Technologies Roadmap

Figure 7-2 illustrates where the subareas of this technology focus area support the subfunctions' ability to meet the performance parameters and capabilities identified for the spaceport base operational model.



Source: ZHA

Figure 7-2 Advanced Servicing Technology Focus Areas

7.1.2 Command, Control and Monitoring

Technology development and demonstration activities will increase spaceport decision-making ability, operational effectiveness and safety while reducing cost by:

- Providing worldwide CCM communications that are seamless, tailorable, multifunctional, secure, survivable, and easily assessable.

- Providing compatible and interoperable command and control systems that supply information, not just data.

- Improving flight safety decision making and increasing the level of situational awareness.

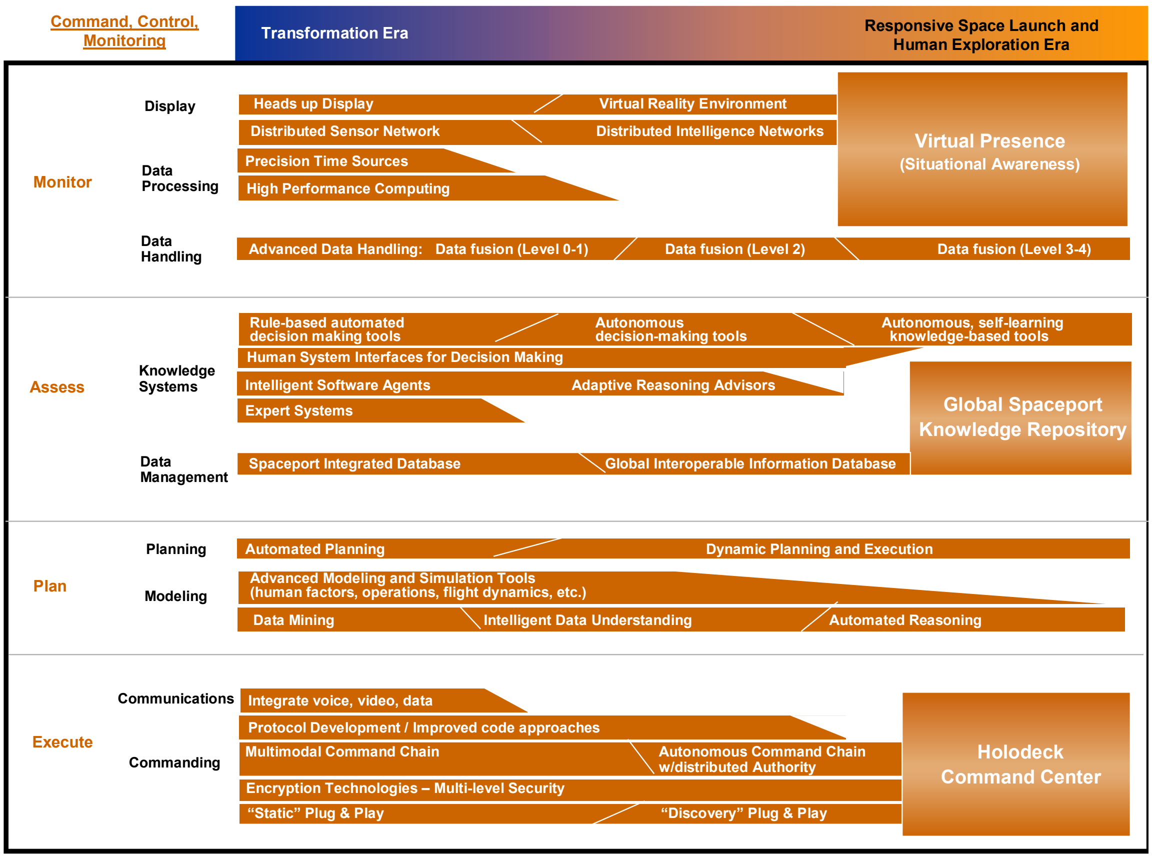
- Enhancing operational efficiency through decreasing the number of unique pieces of monitoring equipment and increasing the capacity for predicting the need for maintenance.

By the first era, technology must focus on improving sensors so that they will be less intrusive, be more reliable than the system they are sensing, be self-calibrating and evaluating to ensure they are operating accurately. Where possible, wireless monitoring systems should be developed. Better integration of the data into efficient display tools that display only information that is relevant rather than an entire data stream needs technological development. Development of a virtual presence is a third era goal of the improvements to the monitoring function.

To better assess the data collected and transmitted, knowledge systems need to be developed. These need to be rule-based, automated systems that assist the human decision makers in the first era. They need to work with a spaceport-wide database of all relevant information on hardware and software to develop a truly electronic workflow. The software needs to be continuously self-validating and verifying. In the second era this database should be expanded to include global data from other spaceports and the global range. Ultimately, a global spaceport and space range data repository would be developed that functions with autonomous self-learning decision-making systems.

The planning function requires advanced modeling techniques to be developed and applied so that the goal of automated planning and simulation can be achieved in the first era. By the start of the third era, techniques in modeling should advance to facilitate automated reasoning.

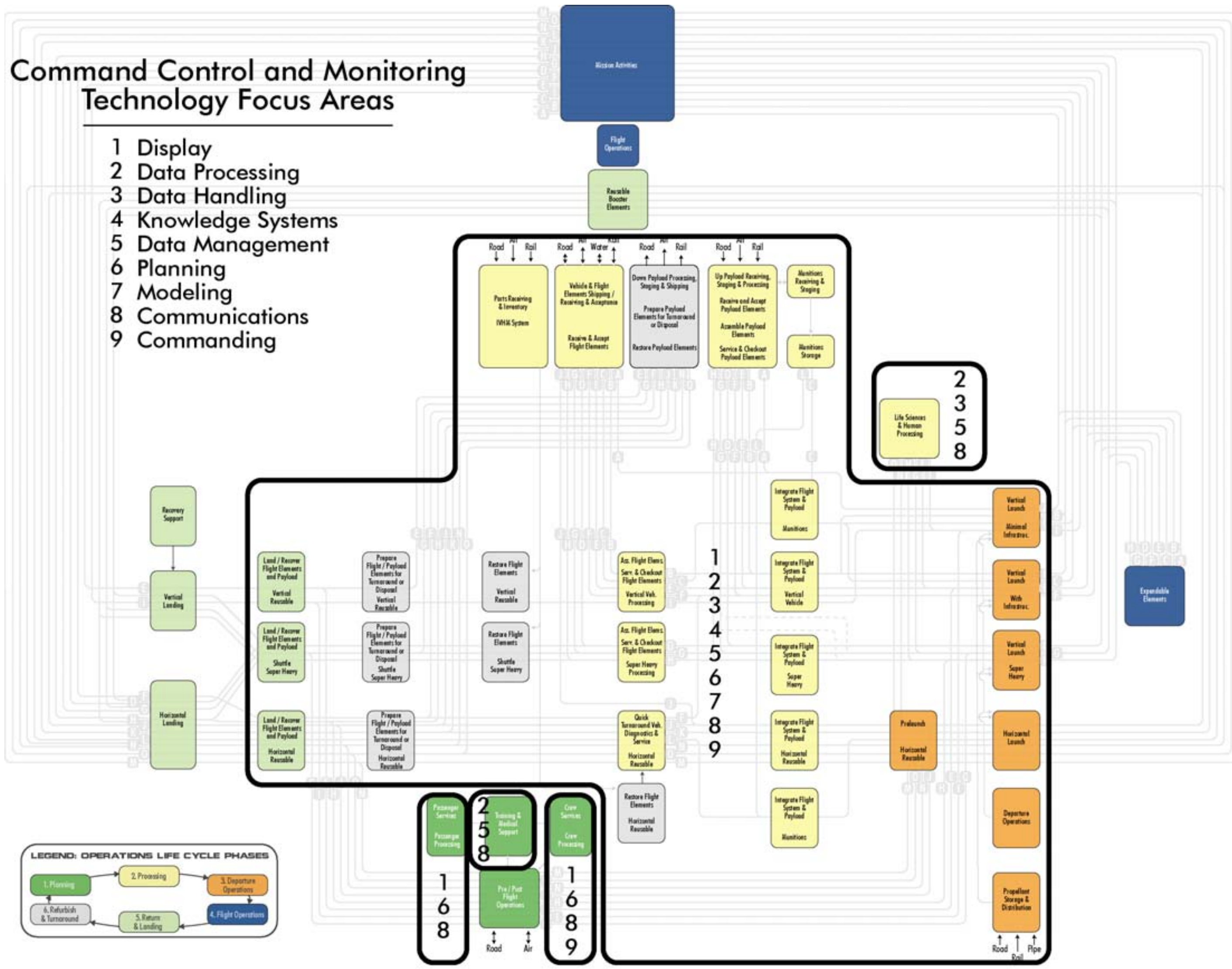
Executing the plan developed with the new technologies requires technological focus to improve communications by developing multimodal command chain communication. The functions at the spaceport need to be integrated into this command and control system with the ability to have autonomous command and control where appropriate. The development of this integrated system should allow distributed command authority and an autonomous command chain by the second era. The Technology Roadmap for Command, Control and Monitoring is shown in **Figure 7-3.**



Source: ASTWG Baseline Report

Figure 7-3 Command, Control and Monitoring Technologies Roadmap

Figure 7-4 illustrates where the subareas of this technology focus area support the subfunctions' ability to meet the performance parameters and capabilities identified for the spaceport base operational model.



Source: ZHA

Figure 7-4 Command, Control and Monitoring Technology Focus Areas

7.1.3 Inspection and System Verification

The enabling technologies should:

- Reduce time and resources involved in vehicle inspection and testing.
- Eliminate duplicate tests and inspection.
- Reduce system damage and vehicle teardown while doing inspections.

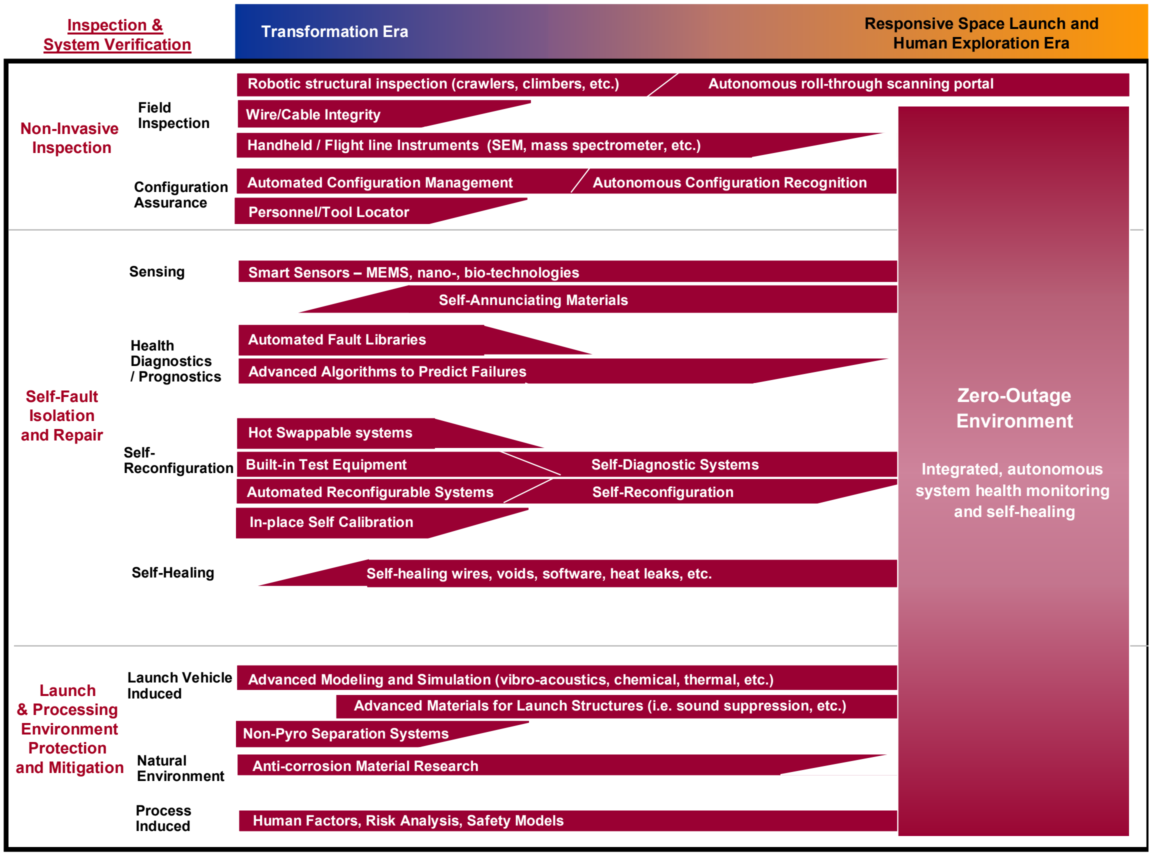
- Increase system and mission reliability and safety.

A primary goal of the enabling technologies is to develop flight and ground systems that self-test and self-repair. These technologies include smart sensors that are non-intrusive and non-destructible, as well as built-in test equipment and automated reconfiguration systems that can recognize a potential problem, reconfigure themselves and self-calibrate. Artificial intelligence systems and advanced algorithms could aid in the prediction of failures and identify when inspections or maintenance was required.

Where external inspection is still necessary, non-intrusive robotic or automated systems should be developed. This could ultimately evolve into a roll-thru scanner much like a medical MRI. Technological advances in hand-held test equipment such as mass spectrometers are also desirable. Automated configuration management, personnel and tool tracking systems are first era goals.

Technologies need to be developed to mitigate or eliminate environmental concerns in the launch process by the use of advanced modeling and simulation and investigation of advanced materials to deal with areas such as sound suppression, corrosion, etc.

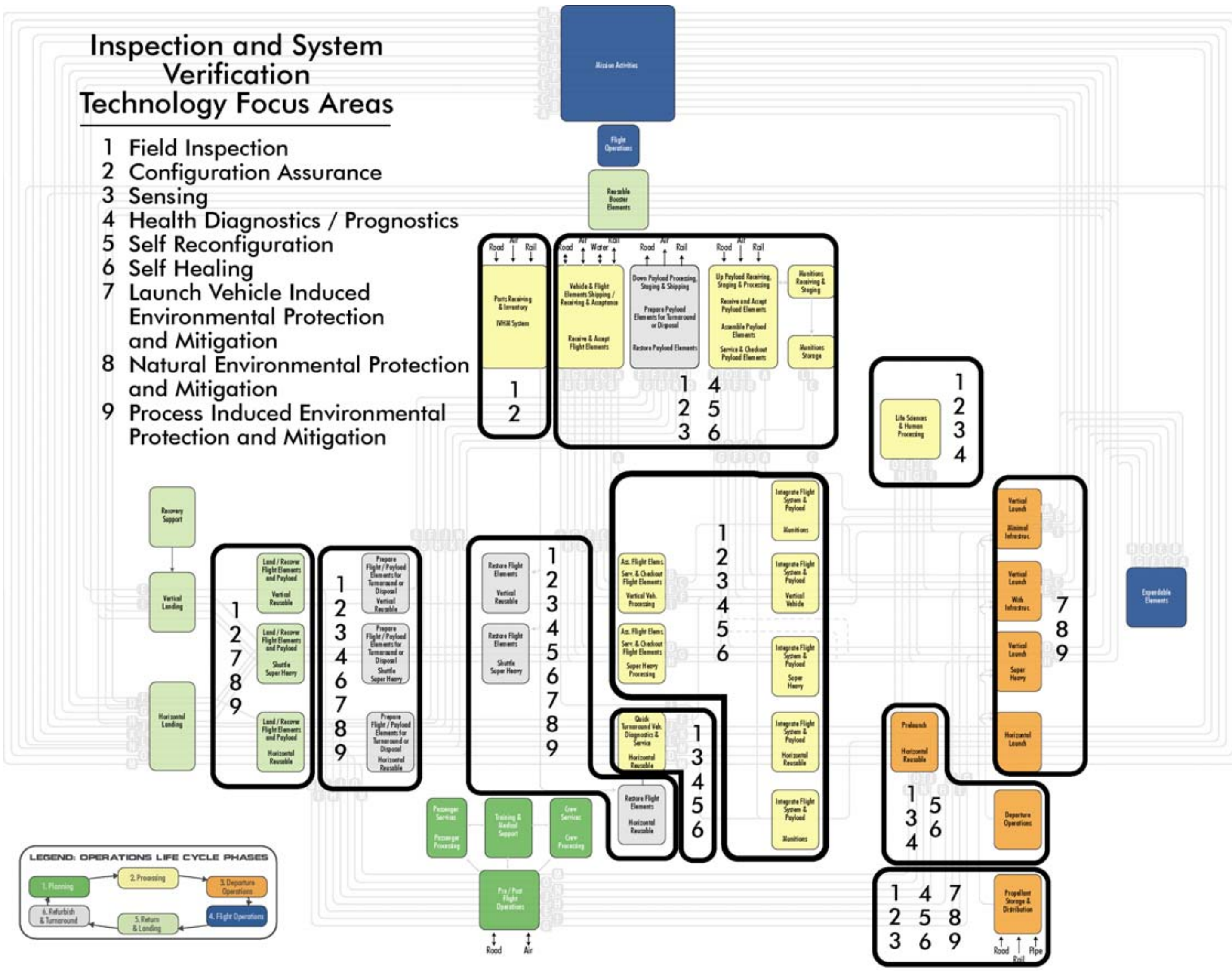
By the start of the third era, the goal is to have an integrated, autonomous system for health monitoring and self-healing. The Technology Roadmap for Inspection and System Verification is shown in **Figure 7-5.**



Source: ASTWG Baseline Report

Figure 7-5 Inspection and System Verification Technologies Roadmap

Figure 7-6 illustrates where the subareas of this technology focus area support the subfunctions' ability to meet the performance parameters and capabilities identified for the spaceport base operational model.



Source: ZHA

Figure 7-6 Inspection and System Verification Technology Focus Areas

7.1.4 Transportation, Handling and Assembly

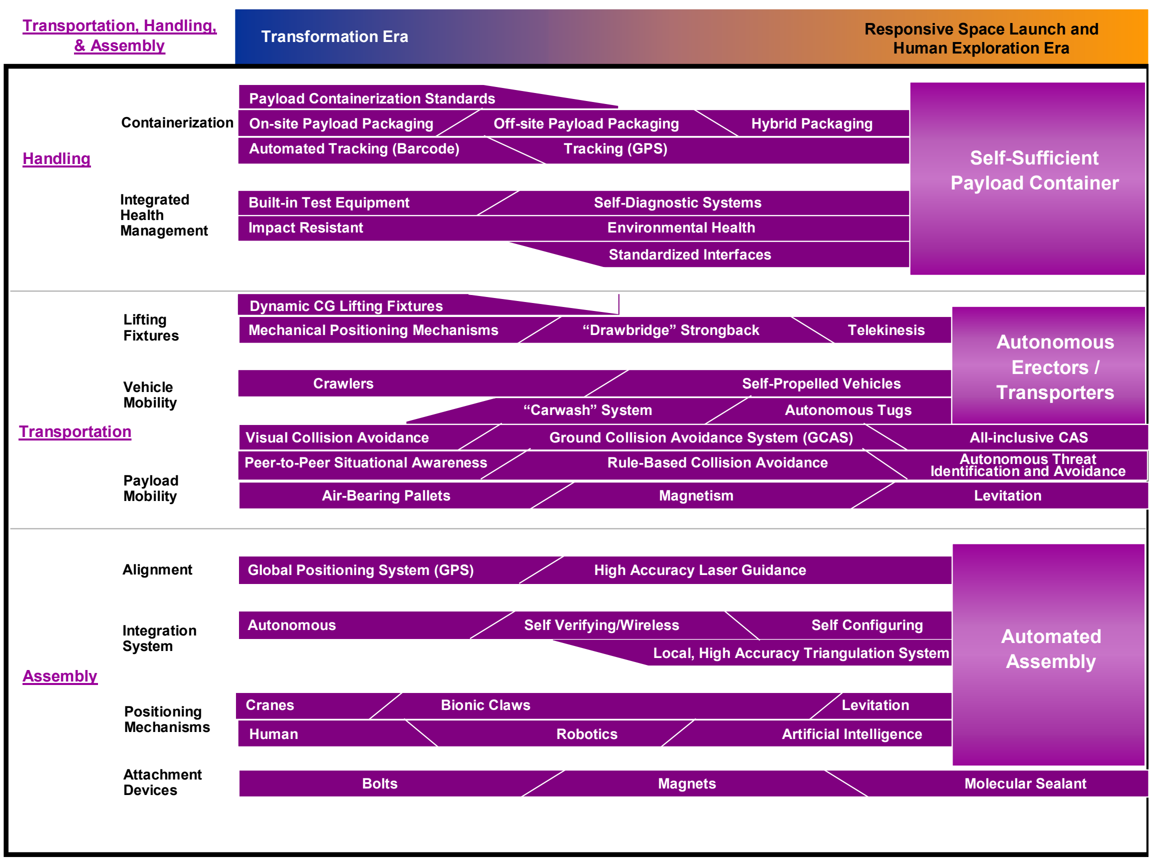
Technology development and demonstration activities will increase efficiency and safety, and reduce costs by:

- Minimizing handling and the number of lifts.
- Minimizing the need for unique handling equipment.
- Minimizing the need for human interfaces.

Handling of flight and payload elements could be improved in the first era by technological advances in containerization with automated tracking and built-in test equipment. By the second era self-diagnostic systems and standardized interfaces should be developed leading to the development of a self-sufficient payload container.

Investigating advanced ground transportation systems for flight hardware could speed movement and reduce the need for support personnel. Similarly, development of robotic and automated lifting devices would reduce the dependence on a large supporting workforce. By the start of the third era, the goal would be to have autonomous erector and transporters with autonomous collision avoidance systems.

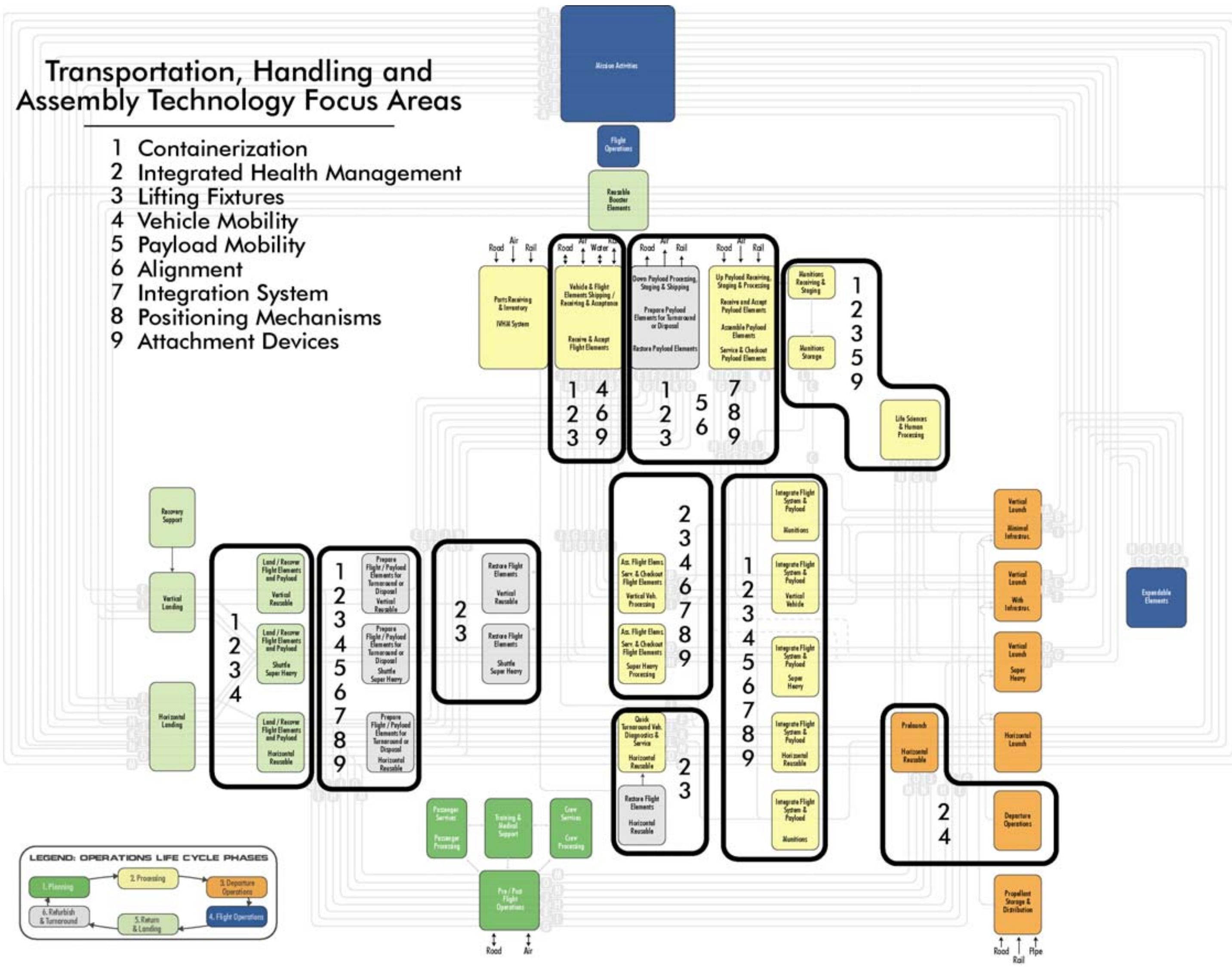
Assembly of payload and flight hardware would be aided by the development of optical and laser alignment and positioning systems and robotics and artificial intelligence with the ultimate goal of achieving automated assembly. The Technology Roadmap for Transportation, Handling and Assembly is shown in **Figure 7-7.**



Source: ASTWG Baseline Report

Figure 7-7 Transportation, Handling and Assembly Technologies Roadmap

Figure 7-8 illustrates where the subareas of this technology focus area support the subfunctions' ability to meet the performance parameters and capabilities identified for the spaceport base operational model.



Source: ZHA

Figure 7-8 Transportation, Handling and Assembly Technology Focus Area

7.1.5 Planning, Documentation, Analysis and Learning

Improving the data collection, monitoring, and decision-making process will:

- Enable a highly efficient, responsive and safe spaceport that maximizes flight rates.

- Create shared information sources to support planning, analysis, and work execution.

- Improve decision making through collaboration.

- Improve the overall PDAL system while minimizing downtime and reducing costs.

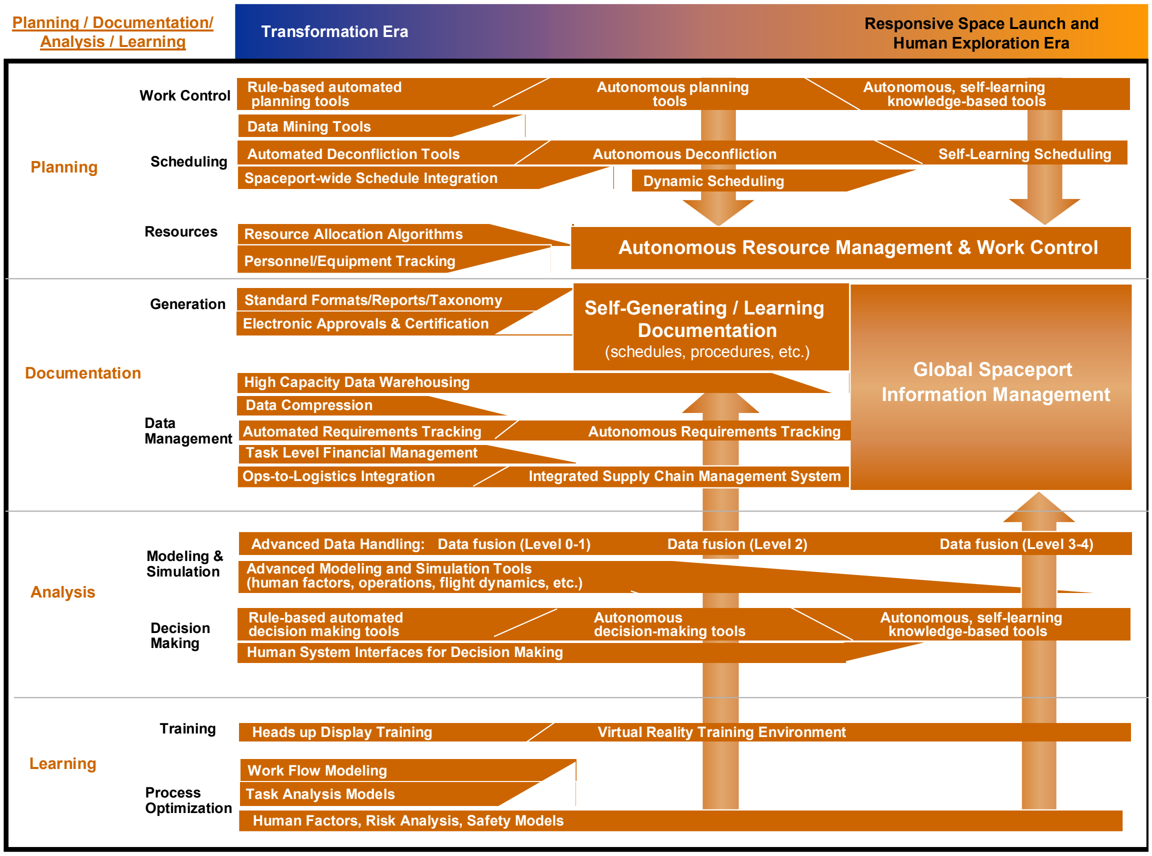
Technology efforts in the area of planning in the first era focus on automating the planning function, providing integrated spaceport scheduling and resource allocation and tracking. As technology moved into the second era more autonomous tools would be developed leading to a self-learning schedule and knowledge-based tools.

Documentation standardization is a goal that must be realized in the first era along with electronic approvals. Better data management and extraction and automated requirements tracking are also first era goals. The analysis of this data will be improved by advanced modeling and simulation techniques and rule based automated decision-making tools.

Another first era goal is human learning by state-of-the-art training tools and simulations. By the second era virtual reality training tools are envisioned.

By the start of the third era a global spaceport information management system that interconnects all of these functions is the goal.

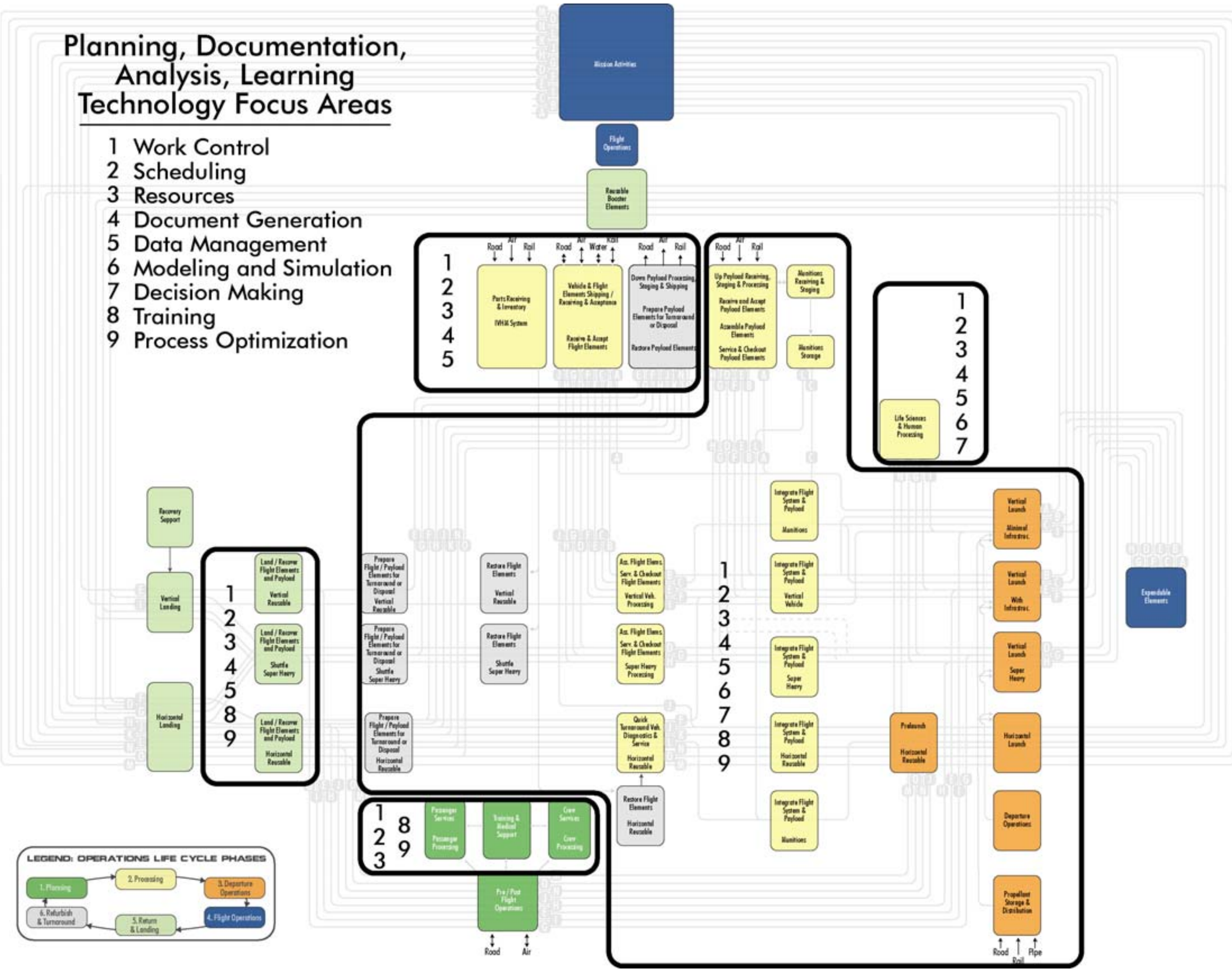
The Technology Roadmap for Planning, Documentation, Analysis and Learning is shown in **Figure 7-9.**



Source: ASTWG Baseline Report

Figure 7-9 Planning, Documentation, Analysis and Learning Technologies Roadmap

Figure 7-10 illustrates where the subareas of this technology focus area support the subfunctions' ability to meet the performance parameters and capabilities identified for the spaceport base operational model.



Source: ZHA

Figure 7-10 Planning, Documentation, Analysis, Learning Technology Focus Areas

7.2 STANDARDIZATION

Even today, the nation's spaceports are the product of substantial investments to provide shared-use checkout and launch support infrastructure. For future spaceport capabilities, standardization is an important element of any strategy to increase availability of shared resources and boost interoperability among vehicles operating from multiple locations—a key element of the vision for future civil, commercial and military space transportation.

Designing flight vehicles to be compatible with a standard set of facility/infrastructure interfaces would reduce the total amount of infrastructure required to support projected future missions, enhance interoperability by providing a common architecture for connecting assets, improve safety and reduce total costs.

Standardization is most economical and operationally beneficial in cases—as envisioned for the third era—characterized by mass public space travel and:

- High flight rates.
- Many different vehicle types interfacing with the same support infrastructure.
- Multiple active takeoff/launch/landing/recovery locations.

Spaceport standards will lead to benefits in designing future spaceport infrastructure in and beyond Earth orbit to support President Bush's national vision for NASA to pursue Moon and Mars exploration. The in-space infrastructure that will be required to support these operations could leverage advanced spaceport technologies developed initially for terrestrial applications.

Examples of areas where standardization will be both beneficial and practical for future spaceports include:

- Documentation and Procedures
- Vehicle Servicing Interfaces and Equipment
- Payload-Vehicle Interfaces
- Payload Containerization and Handling
- Launch Vehicle Handling
- Launch and Landing Facilities

Standardization of support infrastructure is not a new concept, but it is essential to achieve the FIRST vision. Standards will only be accepted if they benefit users by providing economic advantages, improved capabilities, or more efficient operations. Any standards development activities for the future spaceport must be coordinated with and leverage established standardization organizations and processes and must engage government agencies and aerospace industry trade groups as well.

Government agencies and industry trade groups play critical roles in the development of meaningful standards. Government agencies typically have a broader perspective on particular industry aspects and can, therefore, apply a more global solution to an issue. Also, their primary mission is to solve problems with the greater good of the industry in mind, leading to a well-balanced solution. However, their approach must be tempered with the industry needs so as not to stifle development. Meaningful and open dialogue between government agencies, the industry and the stakeholders/users have delivered the best standards.

8.0 SUMMARY

The Future Space Transportation System (FSTS) is envisioned to be a robust, technology enabled and advanced, transportation network that supports national and planetary defenses, government research and exploration, commercial and private ventures, and mass public air and space transportation. This vision includes revolutionary surface, air and space service that supports ever-changing mission and market demands for delivery of payloads, passengers and crew to destinations known and unknown through effective leveraging of public and private resources.

The future spaceport provides flexibility to accommodate diverse user needs within common-use facilities using standardized methods for operating and maintaining air and space vehicles. Commercial, government and military operations share facilities and services achieving unprecedented levels of productivity and efficiency. These system attributes promote responsive access to space, quick turnaround of vehicles and a robust level of activity in the system.

The future spaceport system effectively shrinks geographic distances on earth, reducing transcontinental and transoceanic trip time from numerous hours or days to less than two hours. Market logistics and economies of scale promote the implementation of increasingly advanced hypersonic vehicle operations that are easily integrated into the infrastructure of the future spaceport system without operational restrictions.

The future spaceport system includes a global network of Commercial Transportation Centers that evolved from Airports of the past. These CTCs support hypersonic air and space travel through the common use of facilities and system infrastructure. Various markets are served by CTCs that are scaled in size (tiered) to address passenger and cargo volumes resulting from ever-changing market logistics as well as technology enabled vehicle capabilities.

The former distinction between airports and spaceports is now erased with the functionality of those two previously unique systems integrated into one superior, evolved future spaceport system that is safe and affordable, efficient and reliable, and meets the expectations of all users through consistent service levels.

In addition, it includes incrementally adding capabilities and capacity as needed to meet the needs of projected future national security, civil, and commercial missions in a manner that is consistent with the vision for the future.

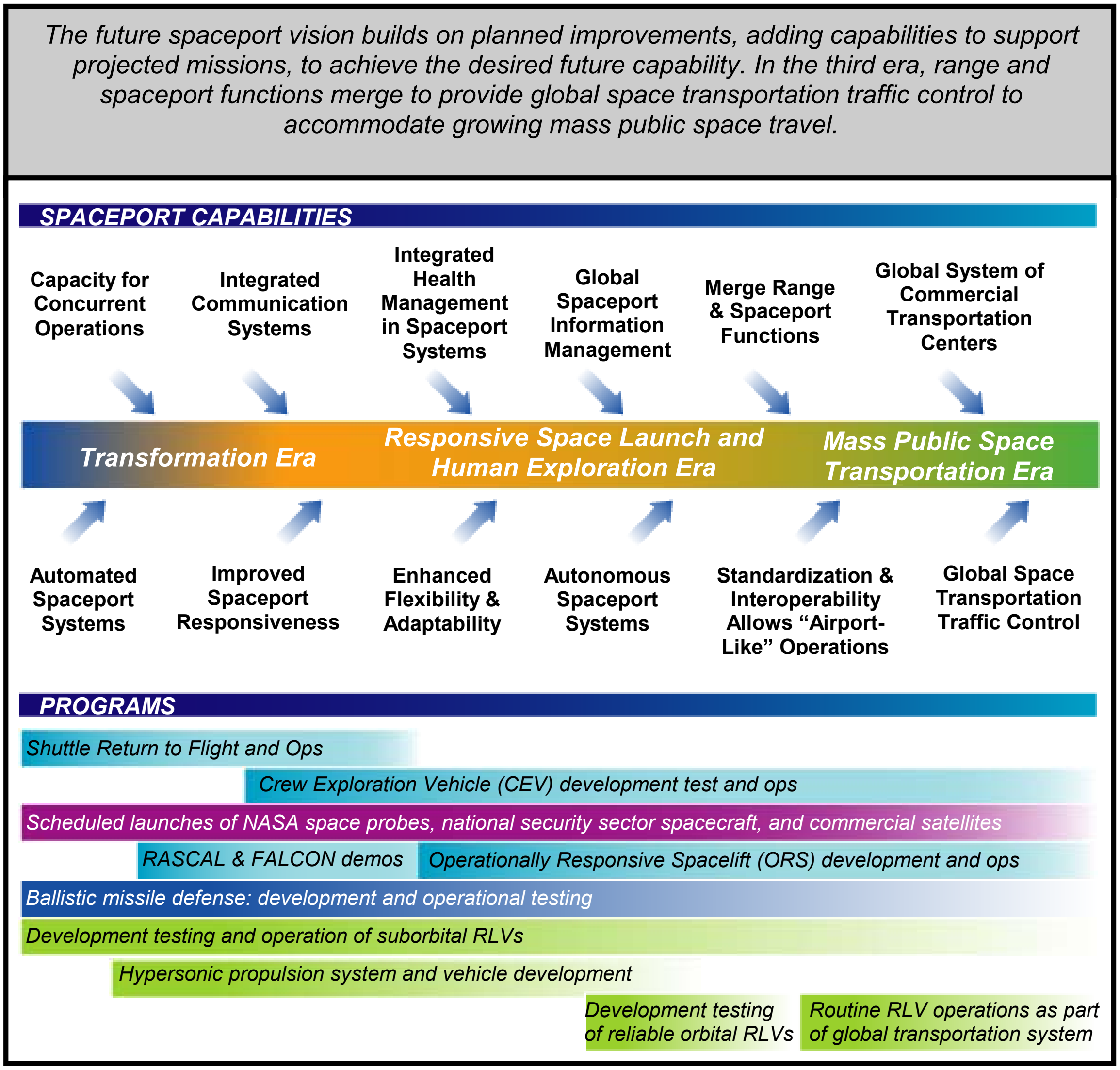


Figure 8-1 Vision for Future Spaceport Capabilities Over Time

In summary, the future spaceport model is envisioned to:

- Ensure safety while providing the capacity to support and enable a variety of future national security, civil, and commercial space launch operations and flight test activities,
- Accommodate short notice-call-up responsive space missions,
- Provide global connectivity using standardized and interoperable systems to support multiple concurrent operations at a variety of dispersed locations,
- Be flexible and adaptable enough to cost-effectively accommodate variations in vehicle configurations and flight rates,

- Make more efficient use of spaceport assets,
- Reduce overall life cycle costs for spaceport capabilities, and
- Provide appropriate protection for spaceport assets and resources, including information.

Achieving these envisioned capabilities in the future requires development of several enabling technologies that will be essential for the successful execution of the future spaceport as described here. The integrated technology roadmap depicted here highlights the time-phased plan for pursuing these technologies.

The following technology focus areas should be pursued to address the technical challenges that stand in the way of achieving the necessary capabilities for each of the spaceport functional areas, as described above.

- Advanced Servicing Technologies to:
  - Decrease the amount of spaceport servicing that is on the critical path;
  - Improve the servicing process.
  - Reduce workforce exposure to hazardous materials.
- Command, Control, Monitoring to:
  - Provide worldwide CCM communications that are seamless, tailorable, multifunctional, secure, survivable, and easily assessable;
  - Provide compatible and interoperable command and control systems that supply information, not just data;
  - Improve flight safety decision-making and increasing the level of situational awareness;
  - Enhance operational efficiency through decreasing the number of unique pieces of monitoring equipment and increasing the capacity for predicting the need for maintenance.
- Planning / Documentation / Analysis / Learning to:
  - Enable a highly efficient, responsive and safe spaceport that maximizes flight rates;
  - Create shared information sources to support planning, analysis, and work execution;

    - Improve decision making through collaboration;
    - Improve the overall PDAL system while minimizing downtime and reducing costs.

- Inspection & System Verification to:
    - Reduce time and resources involved in vehicle inspection and testing;
    - Eliminate duplicate tests and inspection;
    - Reduce system damage and teardown while doing inspections;
    - Increase system and mission reliability and safety.

- Transportation, Handling, & Assembly to:
    - Minimize the need to move items;
    - Minimize the need for unique handling equipment;
    - Minimize the need for human interfaces.

In conclusion, pursuing opportunities for technology development and demonstration activities will enable the development of the future spaceport capabilities described in this CONOPS. Only by developing these capabilities will the future spaceport be able to support the anticipated future missions and achieve the vision for safer and more efficient space transportation for civil, commercial, and national security missions, including eventual mass public space travel to rapidly move people and cargo between points on the globe and into space.

APPENDIX 1 – GLOSSARY

Abort. A premature termination of an operation for any reason. The abort may occur at any point from initiation of an operation to expected completion.

Adequate Source. A data source that meets the performance (e.g., data latency, data accuracy, and data update rate), design (e.g., parts, reliability, and independence), coverage, and certification requirements necessary to satisfy range safety policies and the range user's mission success criteria.

Aeronautical Flight Testing. Test and evaluation activities involving air vehicles, aircraft, missiles and associated weapons.

Airspace. Space above the surface of the earth or a particular portion of such space; usually defined by the boundaries of an area on the surface, projected upward. Controlled airspace is the space within which some or all aircraft may be subject to air traffic control.

Analysis. The verification by quantitative/qualitative evaluation using system, subsystem, or component representation (e.g., mathematical and/or computer models, simulations, algorithms, equations), charts, graphs, circuit diagrams, and representative data or evaluation of previously qualified equipment.

Area Surveillance. Visual and/or instrument monitoring of range hazard areas to ensure that the area is clear of personnel, vehicles, non-mission aircraft, and surface vessels.

Archive. This function stores data for subsequent retrieval.

Asset. Anything available to the range that can be scheduled. Examples of assets include instruments, facilities, vehicles and personnel. Consumables are not assets.

Assured Access to Space. The need identified by National, Department of Defense (DoD), and Air Force space policies to guarantee the availability of critical space capabilities for executing space missions regardless of failures of single elements of the space force structure.

Automated. The application of methods for making processes, functions, algorithms, or equipment self-acting or self-moving; to make automatic.

Availability. A measure of the degree to which an item is in an operable and committable state at the start of a mission when the mission is called for at an unknown (random) time. Availability is dependent on reliability, maintainability, and logistics supportability.

Calibrate. To apply the proper correction factors to standardize an instrument, asset, element, or process to bring it within the specified performance parameters from a known standard.

Centralized. A capability of assets, group of assets, components, functions, or processes anywhere in the LTRS such that they can be monitored, controlled, displayed, recorded, etc.

Circuit. An electronic path between two or more points.

Collect. The acquisition of data from various sources including sensing, signal reception, generation, measurement, and observation.

Commercial-Off-The-Shelf (COTS). Commercial product/equipment designed for commercial use. It is procured exactly as found in the commercial market, and the product/equipment changes and upgrades are the same as vendor provides to his commercial customers.

Concept of Operations (CONOPS). An Air Force document which describes the sequenced actions and capabilities required to generate the desired effects needed to achieve military objectives.

Concurrent. The occurrence of separate activities or events during the same time interval, where the individual steps of the separate activities or events do not necessarily occur at precisely the same time.

Configuration. A collection of interfaced assets of defined state supporting a particular operation or mission.

Configure. The act of arranging components to operate in a defined state.

Countdown. See "launch countdown"

Data. Information that is used as a basis for mechanical or electronic computation, or a collection of facts, numbers, letters, symbols, etc., from which a conclusion can be drawn. Range data may be raw or processed, and in analog, digital, hard copy, and/or electronic formats. Types of data include but are not limited to; telemetry, space object, timing, weather, metric, imaging, range asset health and status, voice, hazard, vehicle uplink, and data products.

Data Processing. The application of procedures that transform or organize data.

Data Product. A deliverable set of data, the content, format, and delivery mechanism of which are specified by the requester or by operational requirement.

Data Reduction. The process of transforming raw data into useful, ordered, or simplified information.

Debris. The parts of a launch vehicle, satellite, missile, or reentry vehicle that are either jettisoned, broken off, or a result of flight termination.

Deconflicted. Asset(s) or group of assets that have no higher priority required, and/or are not scheduled to be in use.

Demonstration. The verification of operation, movement, and/or adjustment of an item performing its specified function under a specified set of conditions, relying on observable functional operation, not the use of instrumentation or special test equipment. Demonstrations typically occur once.

Display Data. Visual presentation of information (e.g., graphical, textual or discrete "image"). Display function determines not only the information to be shown, but the methods of presentation. Various purposes for displays are: 1) Continuous system control, 2) System status monitoring, 3) Briefing, 4) Search and identification, and 5) Decision making. Information can be presented on a surface, cathode ray tube (CRT) window, or screen.

Distribute Data. To prepare data for transmission, including: identification of the destination(s) for data, formatting data appropriate for the destination(s), and presentation of data to the transport media, either physical or electronic.

Environmental Conditions. The aggregate of all external and internal conditions (e.g., temperature, humidity, radiation, magnetic and electric fields, shock, vibration, temperature, etc.) either natural or man made, or self induced, that a device may be exposed to during shipping, storage, handling, and operation that may influence the form, performance, reliability or survival of the device.

Failure. The loss of proper service that is suffered by the user interface to the asset.

Hazard. Equipment, system, operation, or condition with an existing or potential condition that could cause damage or harm to people, property, or the environment.

Hazard Area. The geographical area in which equipment, system, or operation with an existing or potential condition could cause damage or harm to people, property, or the environment.

Hold. A temporary interruption of a launch countdown script.

Hypersonic. Speed five or more times that of sound in air (Speed of Sound – 760mph @ sea level & 59 F)

Image. The representation of an object by optical, microwave, chemical, or other processes**.**

Independent Source. A data source that is electrically, mechanically, and structurally separate from the vehicle guidance and telemetry systems and any other data source as specified in range safety requirements. Structural separation may be achieved on a flight vehicle through proper placement of equipment.

Initial Deployment. The first successful launch and orbital placement for a particular satellite model or constellation.

Instrumentation. Devices or a system of devices used to collect and/or process data.

Interoperability. A measure of the ability to seamlessly share data and information with other sources, systems, agencies, etc.

Launch and Test Range System (LTRS). The current program name used by AFSPC for the combined capabilities of the Eastern Range, headquartered at Patrick Air Force Base in Florida, and the Western Range, headquartered at Vandenberg Air Force Base in California.

Launch Commit Criteria. The implied decision tree which determines the go/no-go decision for the launch. Range safety and the range user will each have their own independent criteria.

Launch Countdown. The operation implementation of the scripted procedure that ends in the "commit to launch".

Life Cycle Cost (LCC). The total cost of an item over the entire span of its lifetime. From a systems perspective, this includes all associated acquisition, activation, operations, maintenance, sustainment, deactivation, and disposal costs.

Maintenance. The technical process of keeping LTRS equipment in an operational state, or repairing a malfunctioning unit once the equipment is in use. The act of preserving LTRS (e.g., hardware, or software) from failure or decline. Maintenance is one element of sustainment that can begin before the system is deployed in the field.

Metric Tracking Data. The information used to determine a target's space position and velocity as a function of time.

National Airspace System (NAS). Defined airspace, procedures, facilities, systems and equipment used for the safe and efficient management and control of aircraft.

No Single Point of Failure (NSPOF). Design characteristic or operational procedure that allows an item (e.g., hardware or software component, asset, or system) to continue to operate within performance specifications in the event of a failure of an item that would normally have resulted in the failure of the system.

Open Architecture. An architecture that employs standards that are widely used, consensus based, published and maintained by recognized industry standards organizations for key interfaces within a system.

Operation. Any procedure requiring the use of range resources.

Operationally Responsive Spacelift (ORS). The means to launch, maneuver, service, and retrieve space payloads so as to enhance military effectiveness, with a goal of undertaking these operations within hours (or days) from notification to launch.

Post-operational Support. Any support activity conducted during the generation state of mission activity.

Reusable Launch Vehicle (RLV). The general term for a launch vehicle which is recovered in its entirety and launched again. A vehicle may be partly reusable and partly expendable, as with the Space Shuttle.

Radio Frequency (RF). The continuous range of electromagnetic radiation used in telecommunications, the frequency of which extends from 3 kHz to 3000 Ghz.

Range Safety. A method by which range operations can be controlled in a reasonable and prudent manner with acceptable risk to people, property, and the environment.

Reconfiguration Time. The time from final range release of an asset from one operation to asset ready to support a countdown or the next scheduled range operation. Reconfiguration is a known, pre-planned activity that includes asset deconfliction, configuration, calibration, and verification. Reconfiguration time excludes asset relocation.

Record. This function stores data, short term, for subsequent playback.

Reliability. Reliability is the probability that a system is operable and can perform its required function for the mission's duration or a specified period of time. For the mission reliability requirements, this is represented by the probability that, under stated initial and operational conditions, the Range will be able to sustain specific functional capabilities over a designated period of time (t, defined below), without incurring a loss of those functional capabilities.

Retrieval. This function allows selective recovery of data from the storage media and provides it to the authorized requester.

Risk. A measure that takes into consideration both the probability of occurrence and the consequence of experiencing an event or force that impacts attaining a goal, objective, or requirement of the baseline plan. The sources of risk include technical (e.g., feasibility, operability, producibility, testability, system effectiveness); cost (e.g., estimates, goals); schedule (e.g., technology/material availability, technical achievements, milestones); and programmatic (e.g., resources, contractual). Risk may be assessed for program, product or process aspects of the system. This includes the adverse consequences of process variability. Risk is measured in the same units as the consequence such as time and/or dollar consequences (loss).

Robustness. A measure of how strongly constructed or sturdily designed an item is; how well an item is designed to fulfill its overall objective.

Schedule [noun]. Published interdependencies of assets allocated to a particular activity or related sequence of activities, set for exact location(s), date(s), and time(s) that do not conflict with the use of assets allocated to other activities.

Security. The measures taken to guard against espionage, sabotage, crime, or attack. Also a measure of the quality or state of being free from danger.

Simultaneous. The occurrence of separate activities or events at the same time but not necessarily beginning and/or ending at precisely the same time.

Single Point of Failure (SPOF). The failure of an item which would result in the failure of the system and is not compensated for by redundancy or alternative operational procedures.

Space and Air Traffic Management System (SATMS). FAA infrastructure that includes space transition corridors (STC), air traffic control procedures, and situational awareness/decision support tools for managing and integrating space traffic operations with air traffic within the National Airspace System (NAS).

Standardization. The use of standard requirements to maintain performance over a wide range of common applications. Standardization applies to hardware, software, services, methods, and other processes.

State. An operational condition of a range asset or configuration of assets.

Sub orbital. Less than one full orbit (as of the earth or moon).

Support. An activity which enables the fulfillment or accomplishment of a separate activity**.**

Telemetry (TLM). The process by which a measurement of a quantity is transmitted from a remote location to be recorded, displayed, or processed.

Termination. Completion of the operation with all required assets approved for release.

Test. The verification through systematic exercising of an item under appropriate conditions, with instrumentation and data collection and processing (followed by analysis and evaluation of quantitative data).

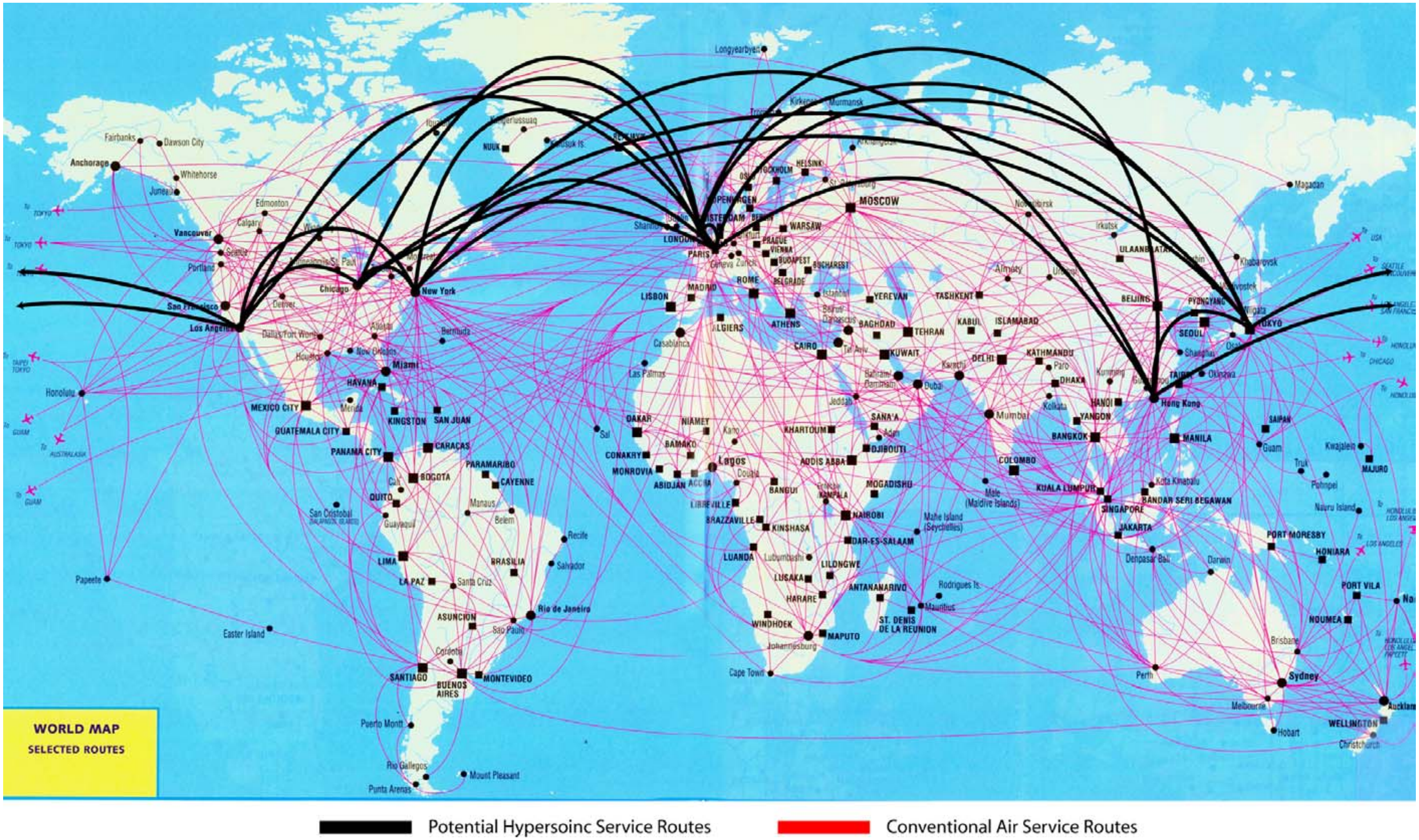
User. A Military organization, Government agency, civil, or commercial organization that makes use of range services and/or facilities.

APPENDIX 2 – ACRONYM LIST

AFSPC	Air Force Space Command
AST	Associate Administrator (of FAA) for Commercial Space Transportation
BMDS	Ballistic Missile Defense Systems
CAIB	Columbia Accident Investigation Board
CAV	Common Aero Vehicle
CEV	Crew Exploration Vehicle
CRT	cathode ray tube
CONOPS	Concept of Operations
CW	continuous wave
DoD	Department of Defense
DOT&E	Director of Operational Test and Evaluation
DSB	Defense Science Board
DRM	design reference mission
EELV	Evolved Expendable Launch Vehicle
EIRP	effective isotropic radiated power
ELV	expendable launch vehicle
EO	electo-optical
FAA	Federal Aviation Administration
FIRST	Future Interagency Range and Spaceport Technologies
FQPSK	Feher's (patented) Quadrature Phase-Shift Keying
FTS	flight termination system
Gbps	giga-bits per second
GEO	geosynchronous Earth orbit
GHz	gigahertz
HAA	High altitude airship
HCV	Hypersonic Cruise Vehicle
HLV	Heavy Launch Vehicle
ICBM	intercontinental ballistic missile
IMU	inertial measurement unit
in	inch
IR	infrared
IVHM	Integrated Vehicle Health Management
KHz	kilohertz
km	kilometer
KSC	Kennedy Space Center
LEO	low Earth orbit
LIDAR	Light (or laser) distance and ranging
LTRS	Launch and Test Range System
m	meter
Mbps	megabits per second

MDA	Missile Defense Agency
MDF	magnetic direction finder
MHz	megahertz
MLS	microwave landing system
MOTR	multiple object tracking radar
MRTFB	Major Range and Test Facility Base
NAS	National Airspace System
NAS-WIS	National Airspace System-Wide Information System
NASA	National Aeronautics and Space Administration
NLDN	National Lightning Detection Network
NSPOF	no single point of failure
OFM	Operational Flow Model
ORS	Operationally Responsive Space (or Spacelift)
OT&E	operational test and evaluation
PCL	passive coherent locator
PGS	Prompt Global Strike
RCC	Range Commanders Council
RF	radio frequency
RLV	reusable launch vehicle
RMC	Reference Mission Configuration
SAR	synthetic aperture radar
SATMS	Space and Air Traffic Management System
SHF	super high frequency
SLBM	submarine launched ballistic missile
SPOF	single point of failure
STC	Space Transition Corridor
T&E	test and evaluation
TDWR	Terminal Doppler Weather Radar
TLM	telemetry
TSPI	time-space position information
UAVs	uncrewed aerial vehicles
UHF	ultra high frequency
UV	ultraviolet
VHF	very high frequency

APPENDIX 3 – INAUGURAL CTC MARKETS AND 1ST TIER ROUTE MAP



Source: OAG Flight Atlas, Dec.'03-Apr.' 4 and ZHA

APPENDIX 4 – MASS PUBLIC SPACE TRANSPORTATION DEMAND ANALYSIS

Economic data considered and used to project mass public transportation demand in the third planning era along with an analysis of average flight times between select world economic capitals at various flight speeds.

World Economic Capitals (Potential Global CTCs)	Population and World Rank of Principal Agglomeration (base market)	Home Country per Capita GDP (relative wealth in terms of domestic production)	Metro Area Civilian Aircraft Passengers (Annual 2002)	Cargo Traffic (Annual 2002)	Statute Miles Between Global CTCs: Tokyo	New York	Los Angeles	London	Paris	Chicago	Hong Kong
Tokyo (HND, NRT)	33,750,000 (1)	$28,700	89,963,084	2,869,745	0	6,740	5,433	5,940	6,034	6,299	1,794
New York (JFK, LGA, EWR)	21,750,000 (3)	$36,300	80,416,807	2,512,899	6,740	0	2,451	3,458	3,624	713	8,054
Los Angeles (LAX)	17,450,000 (8)	$36,300	56,223,843	1,806,164	5,433	2,451	0	5,382	5,588	1,745	7,195
London (LGW, LHR)	11,900,000 (20)	$25,500	92,967,064	1,300,420	5,940	3,458	5,382	0	213	3,950	5,982
Paris (CDG, ORL)	9,850,000 (24)	$26,000	48,350,172	1,481,200	6,034	3,624	5,588	213	0	4,134	5,985
Chicago (ORD, MDW)	9,650,000 (25)	$36,300	83,525,181	1,688,227	6,299	713	1,745	3,950	4,134	0	7,793
Hong Kong (HKG)	7,150,000 (36)	$27,200	33,882,463	2,668,624	1,794	8,054	7,195	5,982	5,985	7,793	0
	Source: Th. Brinkhoff: The Principal Agglomerations of the World (2003-09-16)	Source: The World Fact Book	Source: Airports Council International	Source: Airports Council International	Source: National Geodetic Survey; Encyclopaedia Britannica						

Estimated Flight Times Between Markets at Various Average Flight Speeds (in minutes)

	Tokyo			New York			Los Angeles			London			Paris			Chicago			Hong Kong		
	Conventional	2500 mph	4000 mph	Conventional	2500 mph	4000 mph	Conventional	2500 mph	4000 mph	Conventional	2500 mph	4000 mph	Conventional	2500 mph	4000 mph	Conventional	2500 mph	4000 mph	Conventional	2500 mph	4000 mph
Tokyo				12h 55'	162	101	9h 30'	130	81	12h 55'	143	89	13h 20'	145	91	11h 25'	151	94	5h 15'	43	27
New York	14h 25'	162	101				6h 30'	59	37	6h 50'	83	52	7h 05'	87	54	2h 30'	17	11	18h 15'	193	121
Los Angeles	11h 50'	130	81	5h 25'	59	37				10h 35'	129	81	12h 35'	134	84	4h 05'	42	26	17h 25'	173	108
London	12h 05'	143	89	7h 50'	83	52	11h 45'	129	81				1h 10'	5	3	9h 35'	95	59	12h 00'	144	90
Paris	12h 25'	145	91	8h 25'	87	54	12h 55'	134	84	1h 15'	5	3				9h 35'	99	62	11h 50'	144	90
Chicago	13h 20'	151	94	2h 05'	17	11	4h 25'	42	26	8h 00'	95	59	8h 10'	99	62				15h 50'	187	117
Hong Kong	3h 50'	43	27	17h 30'	193	121	13h 25'	173	108	13h 35'	144	90	13h 20'	144	90	14h 00'	187	117			

Source: OAG Worldwide (Conventional Times)

Assumptions and projections under the baseline scenario for future hypersonic mass public transportation demand.

Baseline Scenario Assumptions			# of annual hypersonic pax (in current figures)	# of annual base market hypersonic pax (in 2040 figures)	# of annual base market hypersonic enplanements	# of annual base market hypersonic departures based on pax capacity of typical vehicle	# of annual hypersonic departures based on vehicle load factor	average # of daily hypersonic departures	**Base** # of daily base market hypersonic departures during peak periods (60 mins.)	**Low (-25%)** # of daily base market hypersonic departures during peak periods (60 mins.)	**High (+25%)** # of daily base market hypersonic departures during peak periods (60 mins.)
Percentage of a/c market shift to hypersonic	**3.0%**										
Capacity of vehicle	**100**	Tokyo	2,698,893	5,505,437	2,752,718	27,527	30,586	84	10	8	13
Load factor	**90%**	New York	2,412,504	4,921,237	2,460,618	24,606	27,340	75	9	7	11
Years of escalation	**36**	Los Angeles	1,686,715	3,440,709	1,720,355	17,204	19,115	52	6	5	8
Escalation rate	**0.02**	London	2,789,012	5,689,270	2,844,635	28,446	31,607	87	10	8	13
Cumulative escalation factor	**2.04**	Paris	1,450,505	2,958,867	1,479,434	14,794	16,438	45	5	4	7
Peak period as a % of daily departures	**12%**	Chicago	2,505,755	5,111,459	2,555,729	25,557	28,397	78	9	7	12
Economic Capitals as percent of world market	**14.4%**	Hong Kong	1,016,474	2,073,492	1,036,746	10,367	11,519	32	4	3	5
		Economic Capitals	Subtotals:	29,700,471	14,850,235	148,502	165,003	452			
			Estimated World Market	206,253,270	103,126,635	1,031,266	1,145,852				
						average # of daily world market hypersonic departures		3,139			

Assumptions and projections under the conservative scenario for future hypersonic mass public transportation demand.

Conservative Scenario Assumptions

Percentage of a/c market shift to hypersonic	1.0%
Capacity of vehicle	100
Load factor	95%
Years of escalation	36
Escalation rate	0.01
Cumulative escalation factor	1.43
Peak period as a % of daily departures	10%
Economic Capitals as percent of world market	14.4%

	# of annual hypersonic pax (in current figures)	# of annual base market hypersonic pax (in 2040 figures)	# of annual base market hypersonic enplanements	# of annual base market hypersonic departures based on pax capacity of typical vehicle	# of annual hypersonic departures based on vehicle load factor	average # of daily hypersonic departures	Base: # of daily base market hypersonic departures during peak periods (60 mins.)	Low (-25%): # of daily base market hypersonic departures during peak periods (60 mins.)	High (+25%): # of daily base market hypersonic departures during peak periods (60 mins.)
Tokyo	899,631	1,287,164	643,582	6,436	6,775	19	2	1	2
New York	804,168	1,150,579	575,289	5,753	6,056	17	2	1	2
Los Angeles	562,238	804,433	402,217	4,022	4,234	12	1	1	1
London	929,671	1,330,144	665,072	6,651	7,001	19	2	1	2
Paris	483,502	691,779	345,890	3,459	3,641	10	1	1	1
Chicago	835,252	1,195,052	597,526	5,975	6,290	17	2	1	2
Hong Kong	338,825	484,780	242,390	2,424	2,551	7	1	1	1
Economic Capitals	Subtotals:	6,943,930	3,471,965	34,720	36,547	100			
	Estimated World Market	48,221,738	24,110,869	241,109	253,799				

average # of daily world market hypersonic departures 695

Assumptions and projections under the aggressive scenario for future hypersonic mass public transportation demand.

Aggressive Scenario Assumptions

Percentage of a/c market shift to hypersonic	5.0%
Capacity of vehicle	100
Load factor	85%
Years of escalation	36
Escalation rate	0.03
Cumulative escalation factor	2.90
Peak period as a % of daily departures	15%
Economic Capitals as percent of world market	14.4%

							Base	Low (-25%)	High (+25%)
	# of annual hypersonic pax (in current figures)	# of annual base market hypersonic pax (in 2040 figures)	# of annual base market hypersonic enplanements	# of annual base market hypersonic departures based on pax capacity of typical vehicle	# of annual hypersonic departures based on vehicle load factor	average # of daily hypersonic departures	# of daily base market hypersonic departures during peak periods (60 mins.)	# of daily base market hypersonic departures during peak periods (60 mins.)	# of daily base market hypersonic departures during peak periods (60 mins.)
Tokyo	4,498,154	13,036,903	6,518,451	65,185	76,688	210	32	24	39
New York	4,020,840	11,653,514	5,826,757	58,268	68,550	188	28	21	35
Los Angeles	2,811,192	8,147,617	4,073,809	40,738	47,927	131	20	15	25
London	4,648,353	13,472,221	6,736,111	67,361	79,248	217	33	24	41
Paris	2,417,509	7,006,613	3,503,306	35,033	41,215	113	17	13	21
Chicago	4,176,259	12,103,961	6,051,981	60,520	71,200	195	29	22	37
Hong Kong	1,694,123	4,910,040	2,455,020	24,550	28,883	79	12	9	15
Economic Capitals	Subtotals:	70,330,870	35,165,435	351,654	413,711	1,133			
	Estimated World Market	488,408,821	244,204,410	2,442,044	2,872,993				
					average # of daily world market hypersonic departures	7,871			

APPENDIX 5 – SPACEPORT CONCEPTUAL ARCHITECTURES

Section 4 of the Spaceport CONOPS describes in general descriptive terms the operation of future spaceports. This appendix expands on those notional descriptions by presenting a discrete set of architecture elements that can be combined in various ways to assemble conceptual architectures. These conceptual architectures are designed to implement the FIRST vision for Spaceport Operations by enabling the Future Space Transportation System (FSTS) to perform many of the functions shown in Figure 1. These conceptual architectures will provide structure for the identification of capability shortfalls and technology solutions for the spaceport functions of the FSTS.

The FIRST Functional Model provides the main organization for the development of spaceport conceptual architectures. The complete model is shown in Figure 1. The boxes shown in orange represent the functions that are addressed by the spaceport conceptual architectures described in this section.

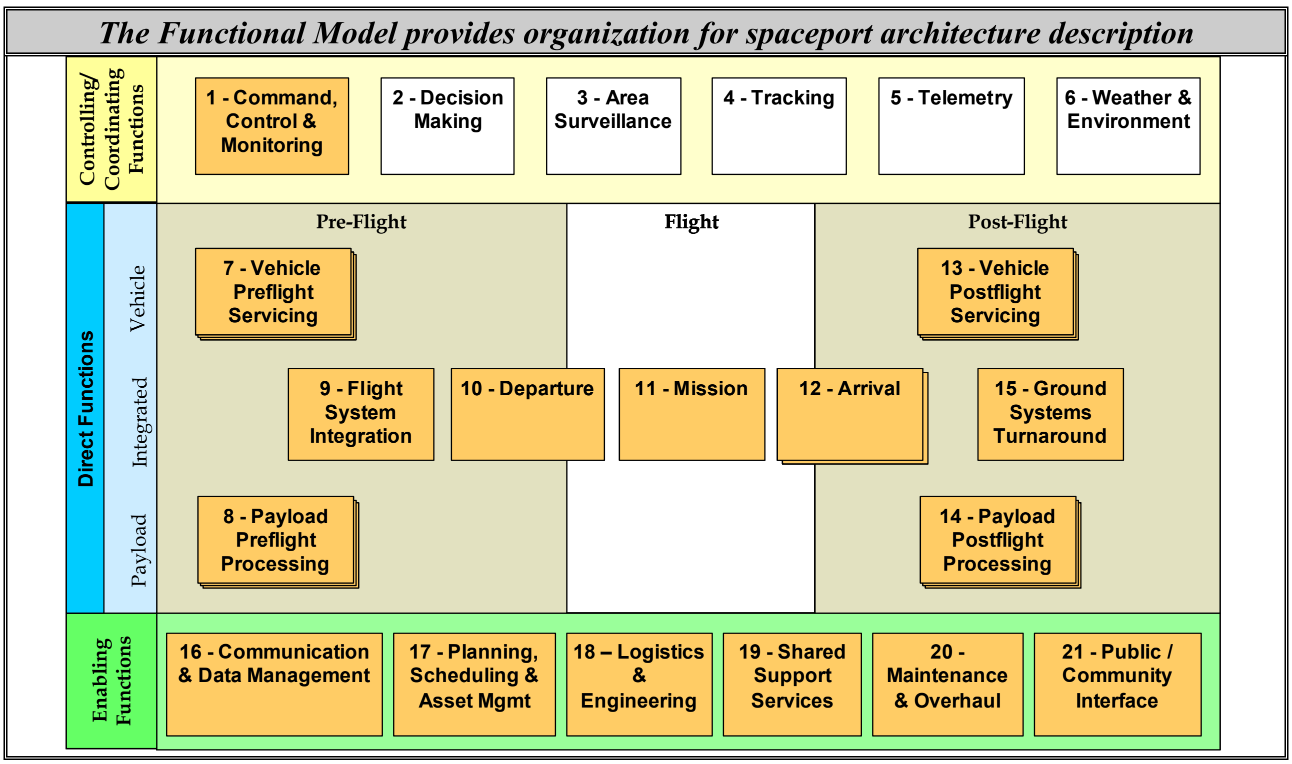


Figure 1 – The FIRST Program Functional Model

The conceptual architectures presented below correspond to 14 spaceport functional groupings identified at a government / industry workshop. Additionally, two Crosscutting Architectures were identified at the workshop that span all spaceport functions.

The conceptual architectures and their correspondence to both the FIRST Functional Model and the Spaceport CONOPS Operations Model are shown in Table 1.

Table 1 – Architecture – Operations Model – Function mapping

Conceptual Architecture	Ops Model	FSTS Function	
Spaceport Information Infra		Communications & Data Management	16
Integrated Health Monitor		Command, Control, & Monitoring	1
Landing & Recovery	R G	Arrival	12
Prepare for turnaround	H1 H2 I1	Vehicle Postflight Servicing	13
Payload Processing	A2 B2 C2	Payload Preflight Processing	8
	I2	Payload Postflight Servicing	14
Quick Turnaround	A0	Vehicle Postflight Servicing	13
Offline Maintenance	O	Maintenance and Overhaul	20
Vehicle Preflight	A1 B1 C1	Vehicle Preflight Servicing	7
Flight System Integration	D1	Flight System Integration	9
Crew & Passenger	D2 D3	Payload Preflight Processing	8
Departure Operations	E S	Departure	10
	J	Ground Systems Turnaround	15
Spaceport Support Services	N	Shared Support Services	12
Monitor and Manage the Flight	F	Mission	11
Ground Traffic Control	K	Command, Control, & Monitoring	1
Logistics	L	Logistics & Engineering	18
Management & community	M	Planning, Scheduling, and Asset Management	17
	P	Public/Community Interfaces	21

PERFORMANCE REQUIREMENTS

To quantify performance requirements for all architectures, Third Era Spaceport Capacity requirements are based on the day-in-the life scenarios / annual mission scenario (see Figure 2 below) in Section 6 of the Spaceport CONOPS and the Design Reference Mission (DRM) detail descriptions from the FIRST Needs Assessment document.

A typical future year, as envisioned for the third era, will include many routine, responsive, and flight test and evaluation activities, with frequent overlapping and concurrent operations.

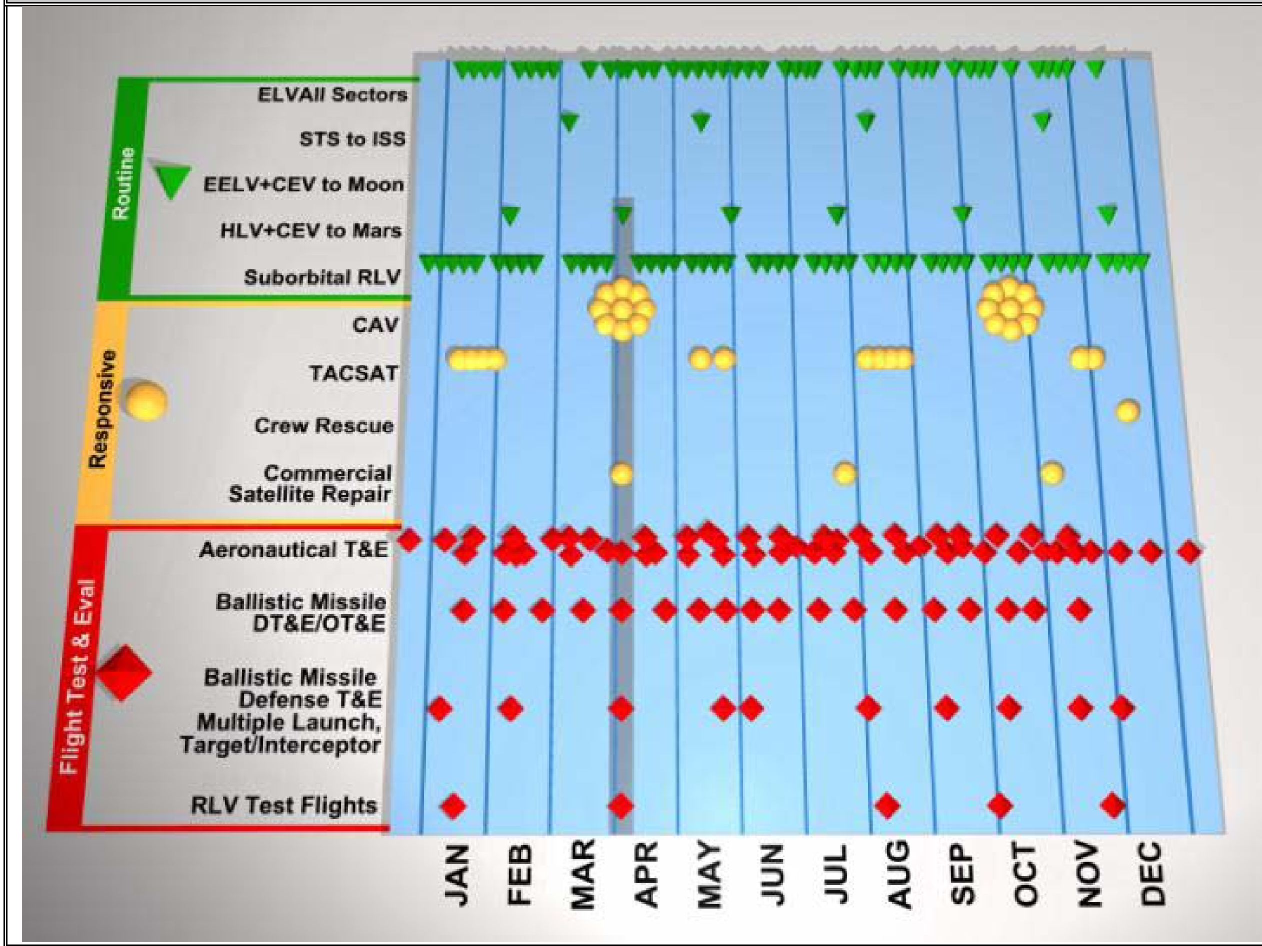


Figure 2 – Third Era Annual mission projection for Day in the Life Scenarios

Additionally, Third Era (2040) Mass Public Space Transportation flights are identified where appropriate. The baseline projection is based on the average daily flight rate, and average peak hour flight rate, for seven major world economic capitals. Mass Public Space Transportation flight rate projections can be found in Appendix 4 of this document.

<u>Baseline:</u>

Average of base projection = **65 hypersonic departures per day** from each spaceport

Average of low and high projections = **6 to 10 departures in a peak hour**

The incremental deployment of technologies and standards throughout the previous two eras can be viewed as an incremental, spiral development approach toward a global space transportation model that provides routine, affordable travel to, through, and from space. Spaceports and vehicles comply with compatibility standards in this era, resulting in global interoperability across spaceports, vehicles and various types of control centers. This degree of interoperability allows practically any type of reusable space flight vehicle to be processed, launched from, or landed/recovered at virtually any spaceport worldwide. The global network of spaceports—each with standardized interfaces—enables routine hypersonic point-to-point flights to destinations around the world.

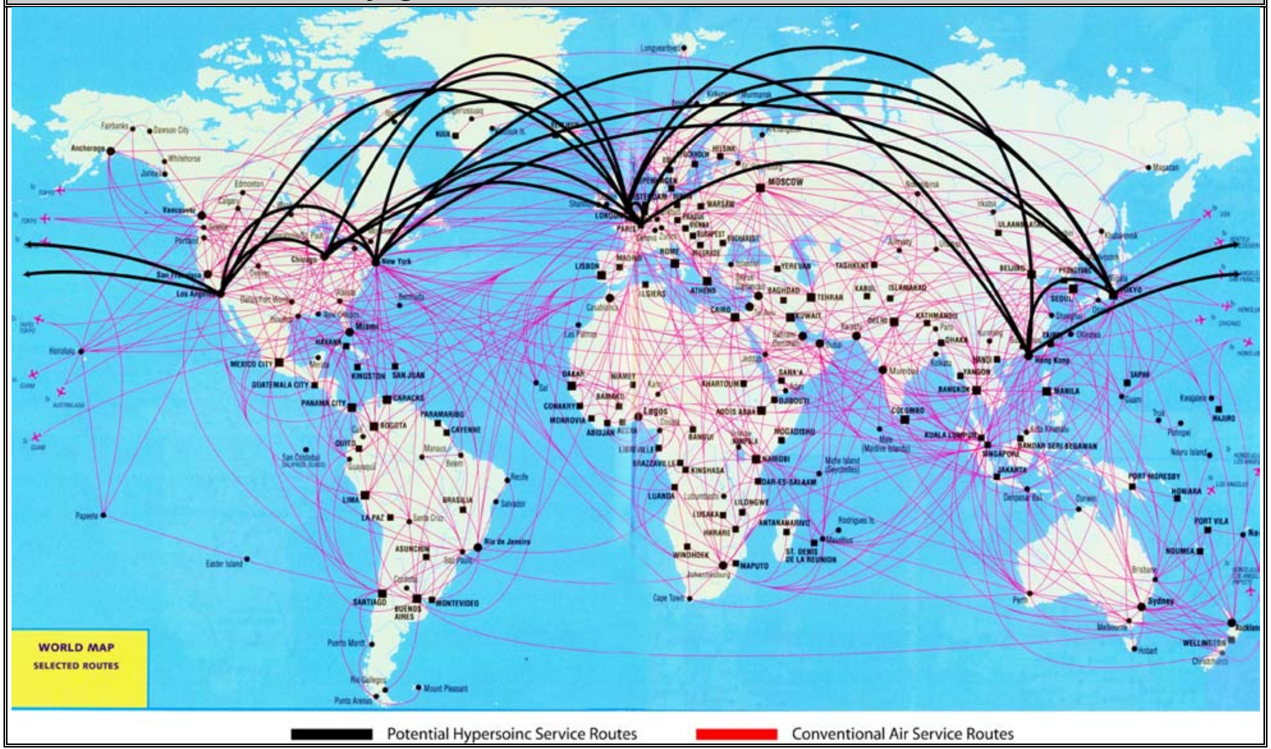


Figure 3 - Spaceports around the World

CONCEPTUAL ARCHITECTURE ELEMENTS

Each spaceport conceptual architecture consists of a set of interconnected architecture elements that represent *Spaceport systems*. These elements are combined in various groupings to support each of the spaceport functions. Each architecture element is described in detail where it first appears in this narrative and thereafter is referred to by its title only. The mapping of these architecture elements to the various functional architectures is summarized in Figure 4.

Many architecture elements are used repeatedly in a variety of conceptual architectures.

	1. Landing & Recovery	2. Prepare for Turnaround	3. Payload Processing	4. Quick Turnaround	5. Offline Maintenance	6. Vehicle Pre-Flight Servicing	7. Flight System Integration	8. Crew & Passenger	9. Departure Operations	10. Spaceport Support Services	11. Monitor & Manage the Flight	12. Ground Traffic Control	13. Logistics	14. Management & Community
Spaceport Information Infrastructure (SII)	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Integrated Health Monitoring (IHM)	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Precision Guidance System	X								X					
Universal ground transportation/handling system	X	X	X	X	X	X	X		X	X		X	X	
Precision Local Positioning System (PLPS)	X													
Post-flight safing and de-servicing equipment	X													
Common Shared Vehicle Processing Facilities		X				X								
Common Shared Payload Processing Facilities		X	X				X							
Payload Containerization System		X	X	X			X							
Quick-Turnaround Infrastructure		X		X		X	X							
Automated Maintenance Planning Systems					X					X			X	
Receiving & Acceptance Facilities			X		X	X							X	
Vehicle/Payload/Ground Interface Systems		X	X	X	X	X	X	X	X					
Flight Vehicle & Payload Integration Systems		X		X			X							
Universal Personnel Ground Transport System	X	X						X	X			X		
Passenger & Crew Preflight and Postflight Facilities								X						X
Space Tourism Facilities								X						X
Shared Departure Points (Clean Pads/Runways)									X					
Automated Fueling / Servicing Systems				X		X			X				X	
Noise Abatement / Blast Protection Systems	X								X					
Hazard Neutralization / Waste Disposal Systems	X	X	X		X				X	X			X	
Spaceport Safety & Security Systems										X		X		X
Infrastructure for Customers / Operators		X	X	X	X	X	X		X	X	X		X	X
Communications Systems	X							X	X	X	X	X		
Surface Traffic Management Systems	X	X					X	X	X			X		X
Weather Monitoring Systems	X								X	X	X	X		
Intermodal Transportation Interfaces			X		X	X				X		X	X	X
Warehousing Systems													X	
Spaceport Sustaining Engineering Systems													X	X
Consumables Acquisition, Storage & Distribution			X	X		X			X				X	
Training & Certification Systems								X		X			X	
Business Planning & Management Systems														X
Community Outreach Systems								X			X			X

Figure 4 – Correlation of Architecture Elements with Conceptual Architectures

FUNCTIONAL CONCEPTUAL ARCHITECTURE DESCRIPTIONS

The following conceptual architectures correspond to FSTS functions as identified in Table 1.

1 LANDING AND RECOVERY

Capability Description:

This is the arrival infrastructure and systems that support landing or recovery of flight vehicle elements. This includes cleared landing zones, runways, landing assist systems, navigation aids, vehicle access provisions, environmental concerns, and any other systems directly involved with vehicle flight recovery. The function supports vehicle Reentry, Terminal Flight, touchdown/rollout, and surface recovery phases of vehicle flight operations.

Top Level Performance Requirements:

- Landing and recovery of flight elements and payloads completed within minutes to hours
    - Integrated Health Management (IHM) system provides continuous vehicle subsystems, payload subsystems, and passenger health monitoring throughout recovery operations
    - Spaceport receives IHM data from flight vehicle during approach and landing
- Landing and recovery in TBD% of weather conditions
    - Spaceport supplies Real-time Environment data for recovery operation
    - Operational elements minimize environmental/toxic impacts
- Time from landing (i.e., wheel stop) or recovery to hangar or staging area within one hour
    - Automated vehicle safing
    - Remote/autonomous payload safing/reconfiguration
    - Robotic towing vehicles to minimize personnel required for recovery
    - Common, shared-use ground support equipment
- Autonomous data archive from payload operations/experiments
- Decouple flight vehicle and payload within one hour
    - Automated disconnect and transport
- Continuous health monitoring
- Standardized command/control systems
- Arrival traffic management seamlessly integrated with airspace/range
- Standardized, simple, integrated decision process and tools
- Real-time Environment data

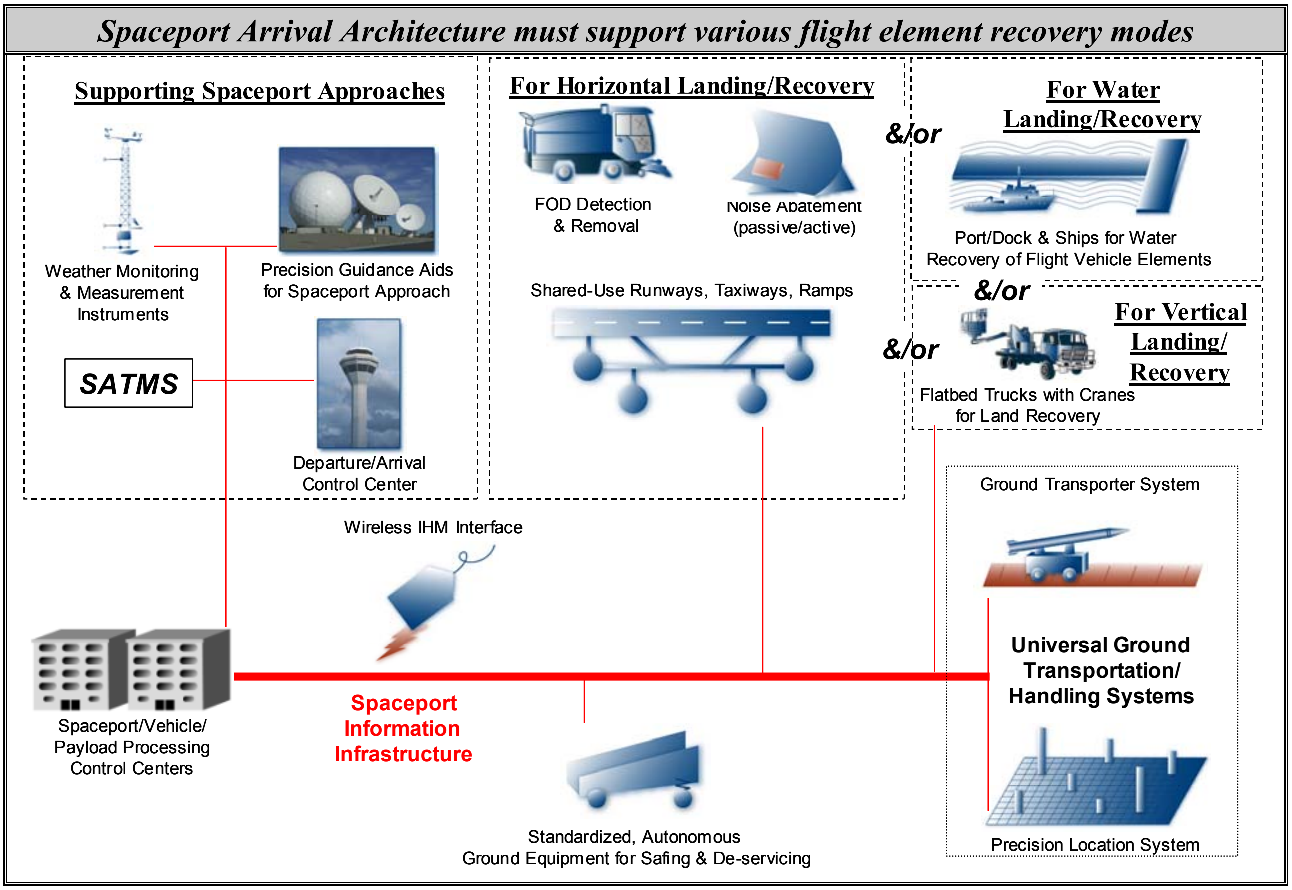


Figure 5 – Arrival Architecture

Description of Architecture:

The Arrival Infrastructure provides Automated landing support systems to support returning flight vehicles/stages/cargo containers approaching the spaceport.

The detailed elements of the Arrival architecture include:

- Universal departure/arrival points (shared landing area/runway) consisting of:
  - Runways for landing and taxiways and ramps for ground transfer of horizontal landing vehicles
  - Facilities, systems, and equipment to accommodate vertical and horizontal landing and recovery options
  - Passive/active noise abatement (ducting/deflecting, cancellation, absorption)
  - Weather/environmental monitoring systems
  - Foreign object damage (FOD) detection and removal

- Precision Guidance System (enabling all-weather capability), including navigation aids (e.g., lights, radio beacons) and instrumentation (e.g., DGPS) to define standard shared use approach corridors for flight vehicles returning to the spaceport

- Precision Local Positioning System (PLPS) provides precise location and orientation information for tagged equipment and elements. The PLPS is used for vehicle access alignment, processing equipment, movement of vehicle and payload elements, and automated servicing interfaces

- Universal ground transportation/handling system consisting of:

    - Automated towing and tug systems with adaptable tow bars to transfer horizontal-landing vehicles from point to point on the ground, as necessary,

    - Transporters with automated, standardized interfaces and super conducting magnetic or air bearing pallets to transfer vertical-landing vehicles from point to point on the ground, as necessary

    - Port/dock facilities and ships for spaceports with coastal locations, to recover reusable stages/vehicles/cargo containers from ocean areas (e.g., after parachute or parafoil landings)

    - Flatbed trucks with cranes and specialized fittings to recover and transport reusable stages/vehicles/cargo containers from open land areas remote from the spaceport itself (e.g., after parachute or parafoil landings, after vertical landings)

    - Robotic handling equipment for use inside vehicle/payload/cargo processing facilities (e.g., magnetic or air bearing pallets, laser alignment, artificial vision/object recognition systems, adaptable grapplers, standardized interfaces, etc)

    - Automated adjustable bridges/ramps/conveyors to off-load passengers, crew, cargo, payloads, containers from reusable horizontal takeoff/landing flight vehicles

- Post-flight safing and de-servicing equipment with standardized/autonomous fittings including scanners to detect potentially hazardous conditions

- Landing site emergency, fire & rescue equipment and contingency recovery systems

- Contingency/emergency landing and recovery sites are identified as adjuncts to spaceport infrastructure and managed by the Global FSTS control network

- Spaceport Information Infrastructure (SII) (see architecture #CC1)

- Integrated health Management (IHM) systems (see architecture #CC2)

2 PREPARE FOR TURNAROUND

Capability Description:

Post-Flight servicing is enabled by the hardware, software, and operations involved in draining, purging, and inerting other consumables as required by vehicle systems. This also includes post flight inspection, system repairs and restoration of flight vehicle elements. Also includes ground support systems that support turnaround ground processing, payload element de-integration from flight elements and preparation for pre-flight operations.

Top Level Performance Requirements:

- Prepare flight elements for turnaround or disposal within hours to one day
    - IHM systems and timed inspections drive informed maintenance approach
    - Robotic and non-intrusive/non-invasive inspection
- Restore flight elements for re-flight within hours to days
    - IHM drives logistics support preparations
- Minimal environmental/toxic impacts
- Continuous health monitoring
- Standardized command/control systems
- Standardized, simple, integrated decision process and tools
- Intelligent Diagnostic & Self-Test
- Vehicle Access & Handling

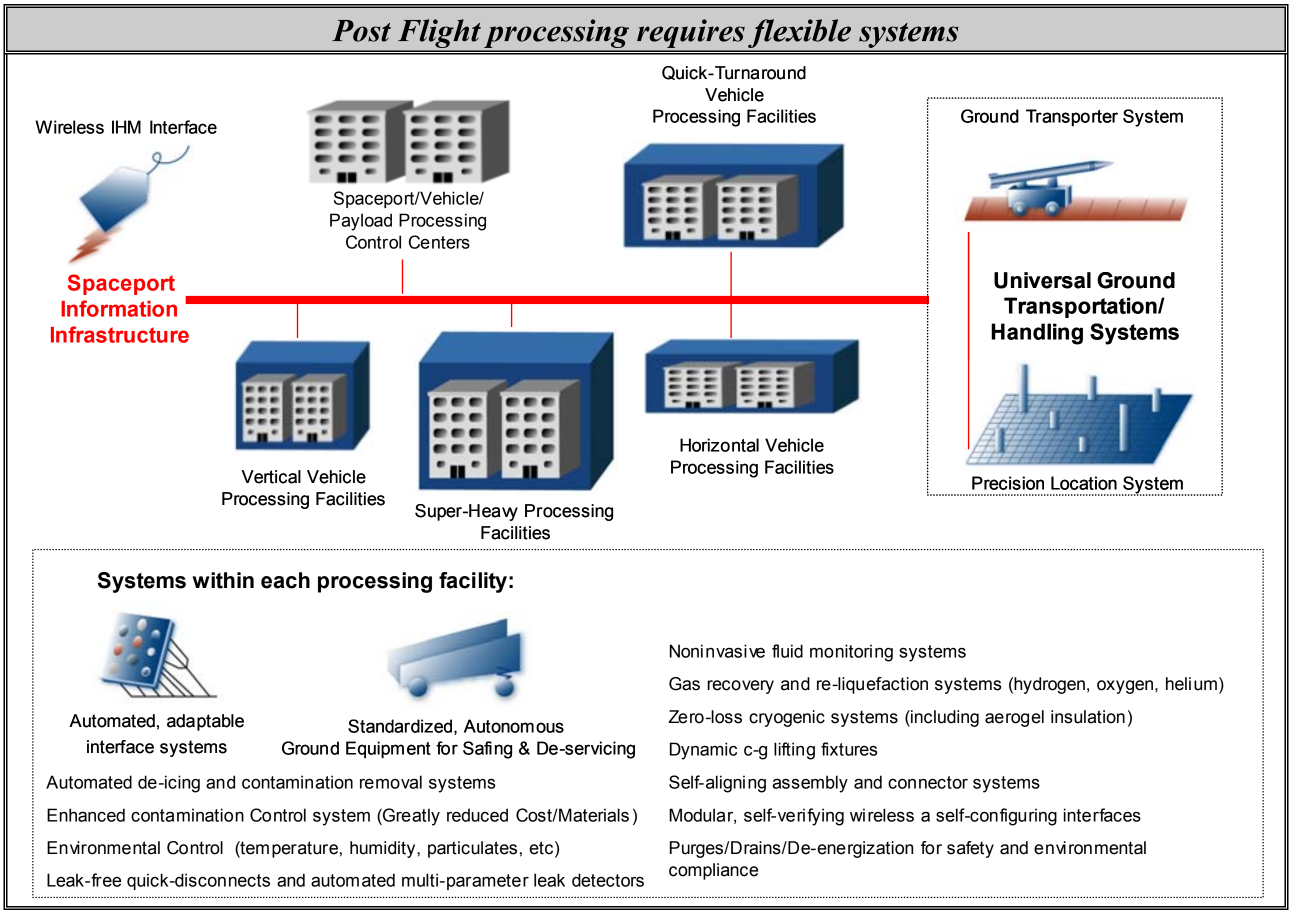


Figure 6 – Prepare for Turnaround Architecture

Description of Architecture:

The Prepare for Turnaround Infrastructure is based upon three types of post-flight processing facilities for removal of returned payloads from flight vehicles, disassembly of flight vehicles (as necessary), disposal of expendable components, servicing of reusable components/elements. The different types are

- For vertical launch/recovery vehicles
- For super-heavy lift vehicles
- For reusable horizontal takeoff/landing vehicles

A Separate quick-turnaround processing facility is envisioned for specific horizontal reusable launch vehicles that require rapid system checkout and servicing prior to the next mission. The details of that alternative architecture are described in 4 Quick Turnaround.

The detailed elements within each vehicle processing facility for turnaround preparation include:

- Common/shared use, automated, adaptable interface systems to accommodate a variety of horizontal takeoff/landing flight vehicles, payloads, and cargo
- Receiving area, with interface to the spaceport universal ground transportation/handling system and supporting Intermodal delivery options
- Automated handling/assembly equipment—in various size classes to accommodate varying sizes and configurations of payload components—to expedite insertion of payloads into ground transport containers, as applicable
- Automated payload element transport system
- Payload quarantine / isolation system
- Automated de-icing and contamination removal systems
- Enhanced contamination Control system (Greatly reduced Cost/Materials)
- Environmental Control system (temperature, humidity, particulates, etc)
- Leak-free quick-disconnects and automated multi-parameter leak detectors
- Noninvasive fluid monitoring system
- Gas recovery, purification and re-liquefaction systems (hydrogen, oxygen, helium)
- Zero-loss cryogenic systems (including aerogel insulation)
- Dynamic c-g lifting fixtures
- Self-aligning assembly and connector systems
- Modular, self-verifying wireless a self-configuring interfaces
- Purges/Drains/De-energization for safety and environmental compliance
- Universal ground transportation/handling system (see architecture #1)
- Spaceport Information Infrastructure (SII) (see architecture #CC1)
- Integrated health Management (IHM) systems (see architecture #CC2)

3 PAYLOAD PROCESSING

Capability Description:

Facilities and hardware/software systems used to receive, prepare, process, pack/load, encapsulate/containerize, checkout, and generally accommodate payloads and cargo before integration with the launch/flight vehicle as well as safing, extraction/removal of cargo and passengers from returning flight vehicle elements. This includes post flight inspection, system repairs and restoration of flight payload system elements. Also includes ground support systems that support turnaround ground processing and preparation for pre-flight payload operations.

Top Level Performance Requirements:

- **Payload Postflight Operations (Disassembly, Refurbishment, and Turnaround)**
    - Prepare payload elements for turnaround or disposal within one day
    - Enable refurbishment/remanufacture of payload elements within hours
    - Rapid/autonomous download/archiving of payload data through port on canister
    - Common hardware/software between pre-flight and post-flight ground equipment
    - Automated maintenance of clean-room environment
    - Ground equipment continuously available, modifications/updates/reconfiguration through software
    - Same ground hardware/software for pre-flight and post-flight payload processing
- **Payload Preflight Preparation (Receipt, Assembly, & Checkout)**
    - Receive and inspect payload elements/subsystems/components within hours
        - Maximize use of containerized payloads with minimal hazards
        - Automated receipt and inspection
        - Automated accounting (e.g., barcode)/nonintrusive inspection of piece-parts
        - IHM to validate payload environment and integrity since factory testing
    - Assemble payload elements within days, for those not received in ready to fly in containers
        - Standard/adaptable assembly and lifting fixtures for payloads and canisters
    - Service and check out payloads within hours to days before flight
        - Common/standard interfaces on payload/panel on canister
        - Automated plug-in
        - IHM system for automated verification and remote testing, with go/no-go indicator/display
        - Enhanced inspection techniques

- Provide sufficient physical security, information security, and OPSEC to enable military (non-munitions) payloads to share use of common processing facilities, as required

- Provide guaranteed Environmental Control for payload processing operations
    - Maintain Temperature within required limits
    - Humidity within required limits
    - Maintain airborne Particulate count within cleanliness requirements
    - Prevent introduction of Contaminants into processing areas

- Support Hazardous Operations for specified payloads as required:
    - Guarantee Personnel protection from all processing hazards
    - Toxic Fluid Servicing
    - Pyrotechnic or energized separation systems
    - Nuclear and Radiation hazards
    - Ordnance / Weaponry handling

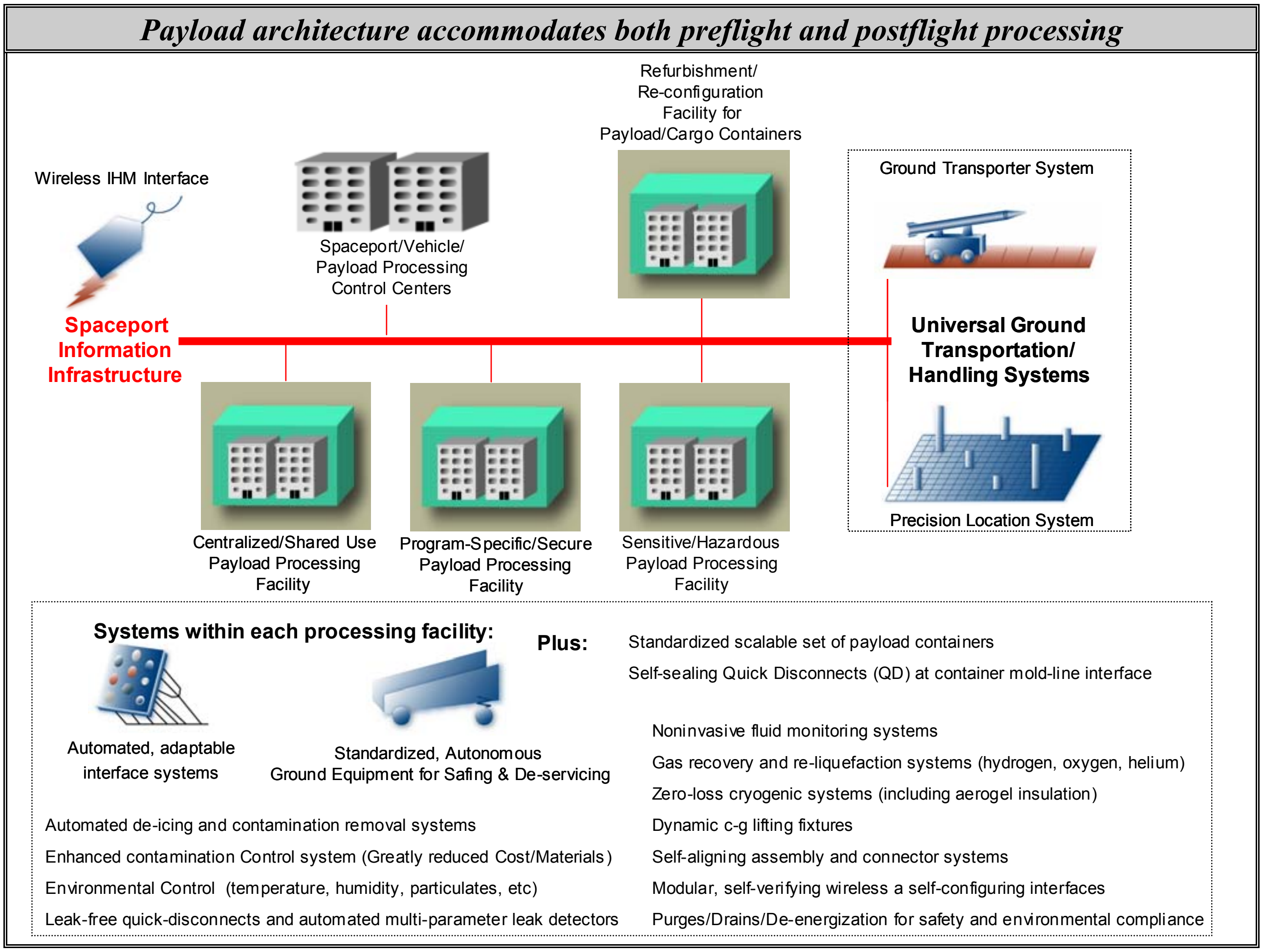


Figure 7 – Payload Processing Architecture

Description of Architecture:

The Payload Processing Infrastructure consists of three general types of operations possible at a given spaceport site:

- Centralized/common/shared use payload/ cargo processing facilities for handling of returned/offloaded commercial payloads/cargo to be serviced/refurbished for another flight, routed to other forms of transportation, or disposal of expendable elements.

- Program-specific, secure facility (located with separation from other facilities for safety) to receive, inspect, stage hazardous military payloads and components containing munitions or national security sensitive payloads/cargo.

- Specialized/dedicated use cargo processing facilities for handling of specific scientifically sensitive or hazardous returned/offloaded payloads/cargo, including for example exotic materials from space manufacture or samples returned from other planetary surfaces.

The detailed elements of the payload architecture include:

- A central payload processing operations facility accommodates both down and up payload customer needs at the spaceport. The facility consists of:
    - Common processing bays
    - Specialized processing areas
    - Multiple reconfigurable work areas/stations
    - Common automated payload assembly and interface equipment
    - Automated container to payload integration and testing equipment
    - Processing control rooms for payload customers
- Separate refurbishment/reconfiguration facility for payload/cargo containers (after payloads/cargo are unloaded from them)

Standardized containers are key to enabling robust payload opertaions

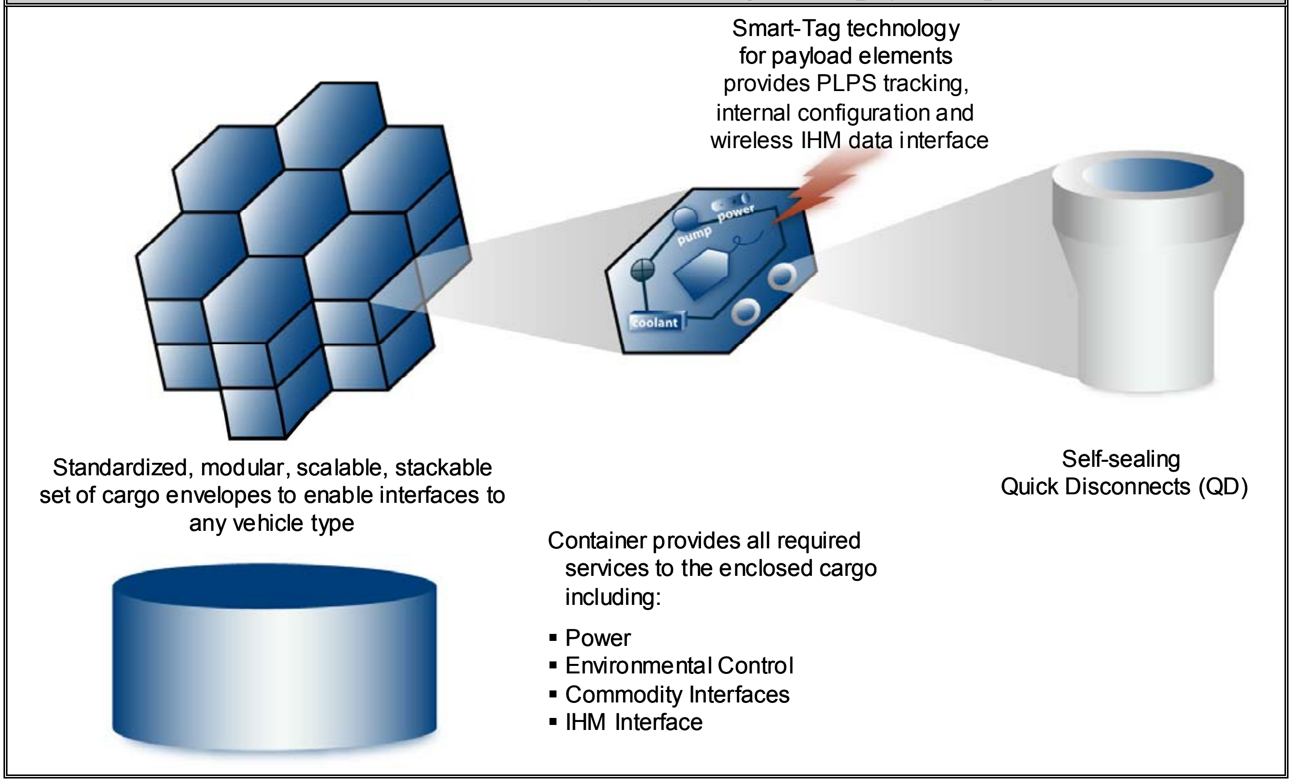


Figure 8 – Payload Containerization Concept

- Payload Containerization System
    - Standardized scalable set of payload containers enabling universal cargo manifesting on any flight vehicle system

  - Most payloads arrive or end up in standardized modular payload containers
  - Payloads are self contained – container provides all required services to the enclosed cargo
  - Smart-Tag RFID technology for payload elements provides PLPS tracking, internal configuration and IHM wireless data interface
  - Self-sealing Quick Disconnects (QD) at container mold-line interface
- Precision Local Positioning System (PLPS) for processing equipment, payload elements, and servicing interfaces (see architecture #1)
- Systems within each vehicle/payload processing facility (see architecture #2)
- Spaceport Information Infrastructure (SII) (see architecture #CC1)
- Integrated health Management (IHM) systems (see architecture #CC2)

4 QUICK TURNAROUND

Capability Description:

Provide ground capability for rapid postflight turnaround of highly responsive reusable flight elements. These are the routine, scheduled activities involved in the normal cycle of operations.

Top Level Performance Requirements:

- Prepare flight elements for turnaround within TBD hours
  - IHM systems and timed inspections drive informed maintenance approach
  - Robotic and non-intrusive/non-invasive inspection
- Restore off-nominal flight element systems for re-flight within TBD hours
  - IHM drives logistics support preparations
- Minimal environmental/toxic impacts
- Continuous health monitoring
- Standardized command/control systems
- Standardized, simple, integrated decision process and tools
- Intelligent Diagnostic & Self-Test
- Hot-Tanks Handling (no routine purge and inerting of Vehicle propellant tankage)

- Minimal Infrastructure

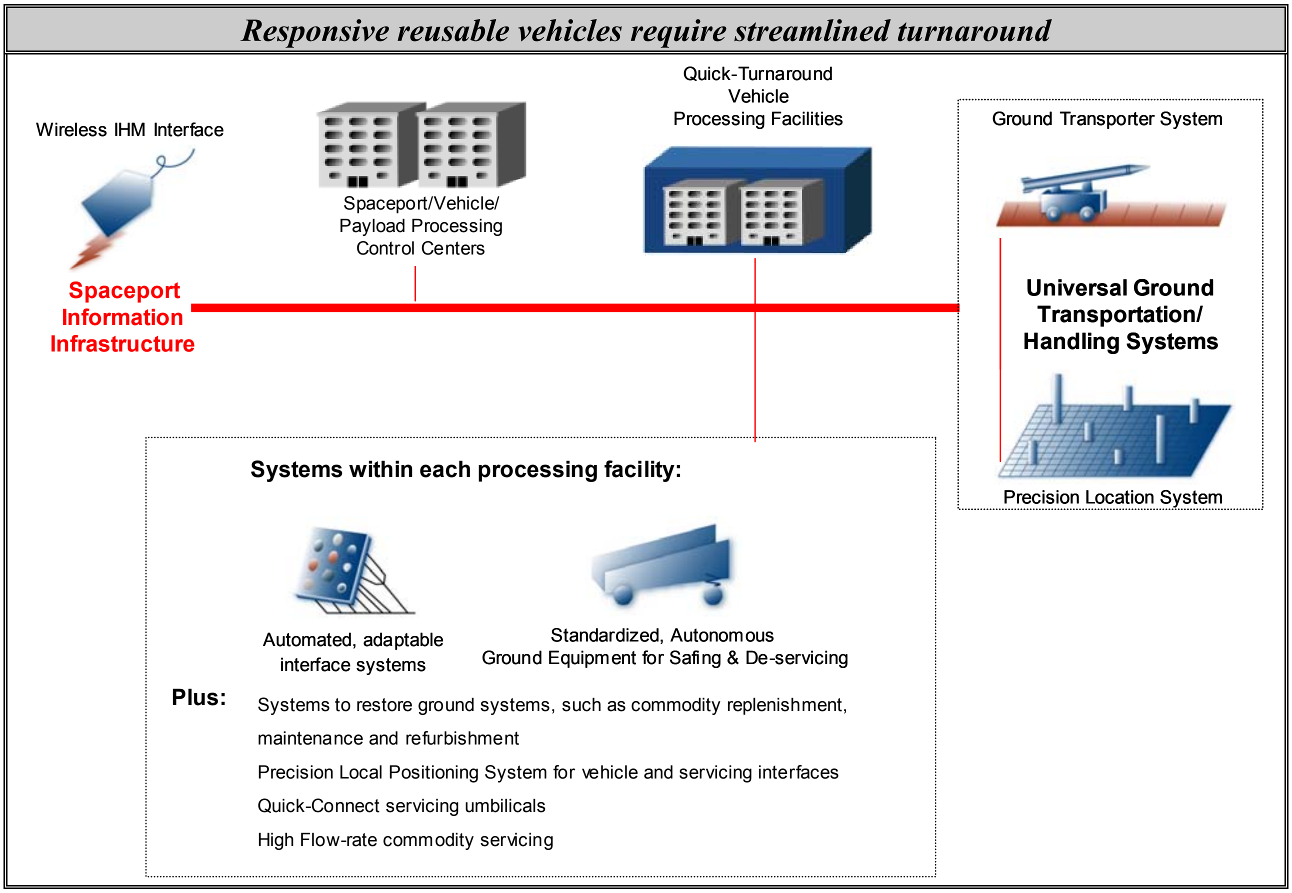


Figure 9 – Quick Turnaround Architecture

Description of Architecture:

The Quick Turnaround Infrastructure is an optimized, highly streamlined version of vehicle post flight and preflight preparations. It is designed specifically for third generation, highly responsive reusable flight elements that are capable of rapid turnaround between flights. This is the "aircraft-like" operations facility that will be a key element of the 3rd era.

The detailed elements of the quick turnaround architecture include:

- Program-specific processing facilities for assembly, processing, and servicing of responsive horizontal takeoff/landing vehicles
- Systems to restore ground systems, such as commodity replenishment, maintenance and refurbishment
- Precision Local Positioning System for vehicle and servicing interfaces
- Quick-Connect servicing umbilicals
- High Flow-rate commodity servicing

- Universal ground transportation/handling system (see architecture #1)
- Systems within each vehicle/payload processing facility (see architecture #2)
- Spaceport Information Infrastructure (SII) (see architecture #CC1)
- Integrated health Management (IHM) systems (see architecture #CC2)

5 OFFLINE MAINTENANCE

Capability Description:

This provides the infrastructure and equipment required for off-line maintenance of spaceport equipment as well as interval maintenance or modification of reusable flight elements. Included are hangars, test equipment, specialty shops, sampling and analysis, tool calibration, system upgrade or modification.

Top Level Performance Requirements:

- Provide for continuous health monitoring during subsystem maintenance
- 100% availability of maintenance infrastructure for spaceport operators & tenants
- Spaceport maintenance infrastructure must not impact critical path of operations

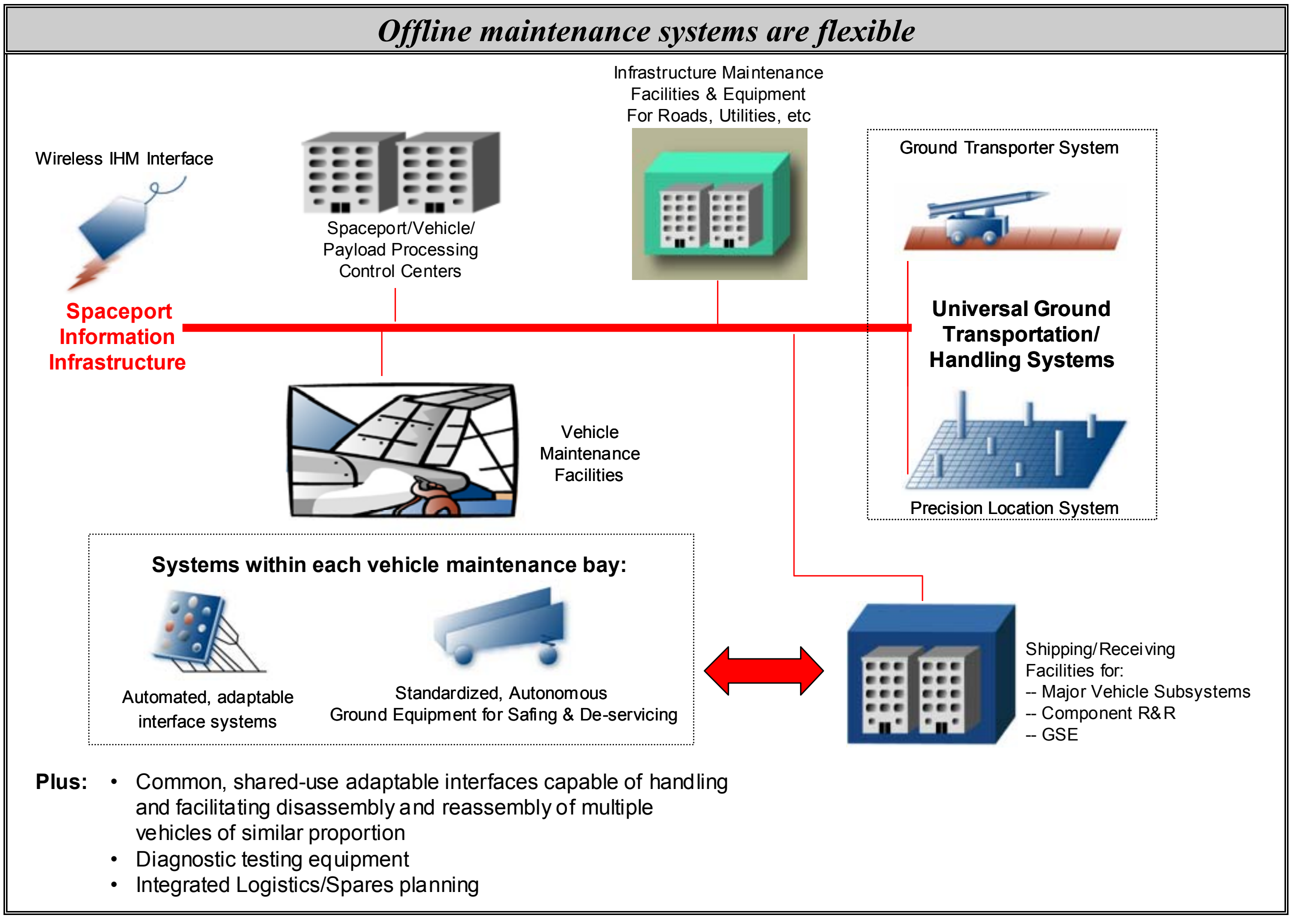


Figure 10 – Offline Maintenance Architecture

Description of Architecture:

The Offline Maintenance Infrastructure provides common-use facilities for overhaul and/or modification of ground equipment, spaceport facilities, and flight elements. This includes automated, non-destructive evaluation and diagnostic systems, open floor work areas with roll-up access and is linked into the IHM and SII architectures where appropriate.

The detailed elements of the offline maintenance architecture include:

- Infrastructure maintenance facilities and equipment (e.g., road maintenance, utility maintenance)
- Spaceport equipment incorporates Intelligent Diagnostic & Self-Test capabilities
- Automated Informed Maintenance (AIM) systems for interval scheduling and optimization of maintenance planning
- Universal ground transportation/handling system (see architecture #1)

- Precision Local Positioning System for vehicle and servicing interfaces (see architecture #2)
- Spaceport Information Infrastructure (SII) (see architecture #CC1)
- Integrated health Management (IHM) systems (see architecture #CC2)

6 VEHICLE PRE-FLIGHT SERVICING

Capability Description:

This includes initial vehicle element receipt at the spaceport. Flight element system, subsystem and component assembly if required. This also encompasses element servicing and pre-integration checkout of systems and vehicle functionality. This is enabled by the hardware, software, operations and ground support systems to support ground processing of flight vehicle elements.

Top Level Performance Requirements:

- Receive and inspect flight elements/subsystems/components within minutes to hours
  - Automated receipt acceptance based on go/nogo criteria
  - IHM for transportation—items arrive ready to fly, only necessary to remove from container
  - Standard receiving process, ground support, fixtures
  - Non-intrusive inspection and accounting for piece-parts
- Assemble flight elements in hours to one day
  - Standardized/foolproof/clocking/self-verifying electrical and mechanical connectors (green light indicator)
  - Standardized handling/lifting equipment (not vehicle unique)
  - Minimal to no hazardous assembly
  - Concurrent assembly operations
  - Certification of subcomponents and streamlined approval processes
- Service and check out flight elements within hours
  - Integrated health Management with automated verification, with macro-level (not subsystem) testing, autonomous testing, self-fault detection, self-healing systems

  - Standardized testing and servicing equipment for each vehicle type/product line
  - Network-based multi-parameter monitoring for safety in the servicing area
  - Maximize remote capabilities
  - Nonintrusive servicing and checkout
- Sufficient flexibility and adaptability to enable multiple vehicles (of similar type/class) to use common spaceport infrastructure
  - Sufficient physical security, information security, OPSEC to enable military vehicles to share use of common processing facilities, as required
- Sufficient flexibility and adaptability to minimize reconfiguration/changes to spaceport systems when vehicle designs change
- Sufficient standardization to operate multiple vehicles the same way at different locations/spaceports

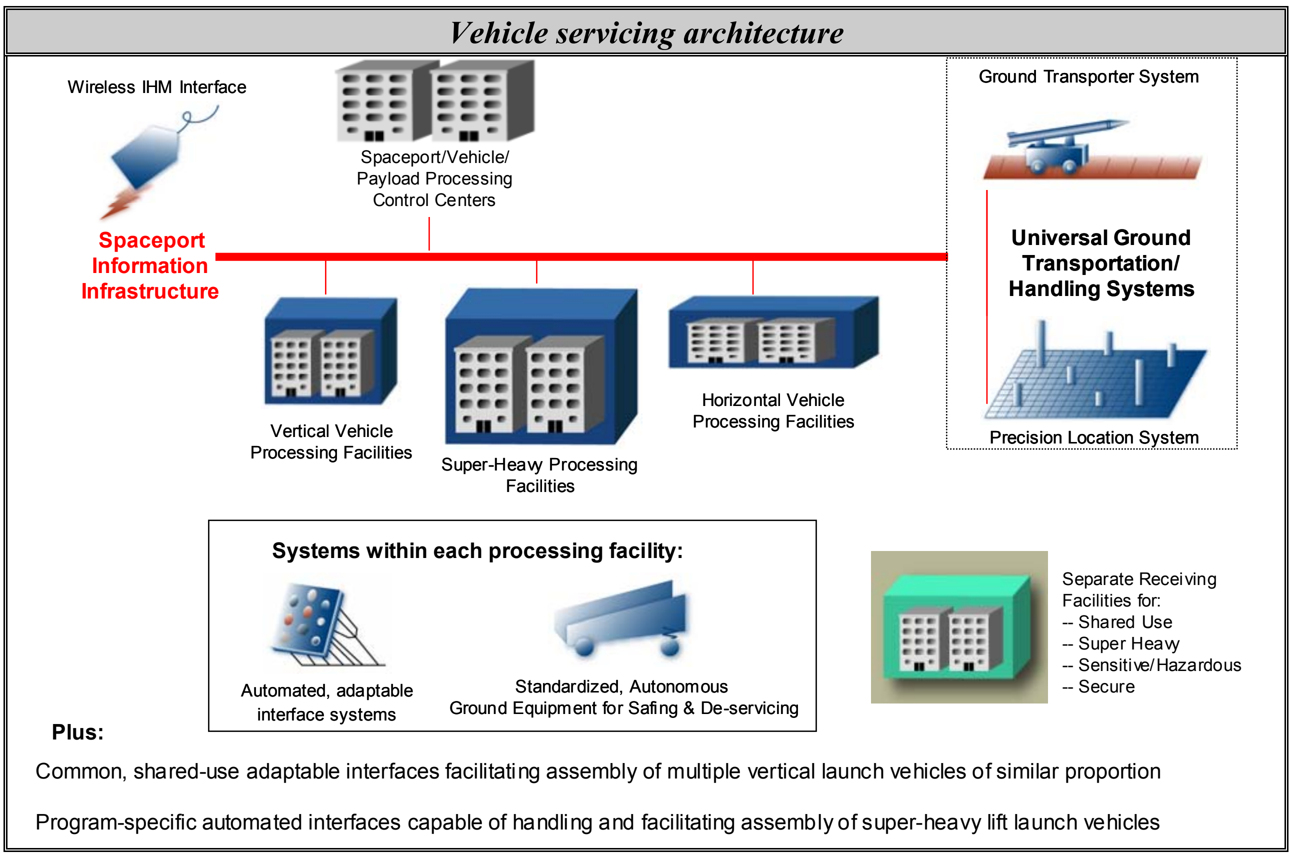


Figure 11 – Vehicle Preflight Servicing Architecture

Description of Architecture:

The Vehicle Preflight Servicing Infrastructure is tailored for some flight vehicle applications. It encompasses the expendable vehicle flight preparation cycle as well as the evolving new vehicle approaches. In the case of reusable flight elements, it generally will share much of the facilities of the Prepare for Turnaround architecture (#2).

The detailed elements of the Vehicle preflight architecture include:

- Spaceport Control Center at each spaceport coordinates use of spaceport facilities and systems
- Vehicle Processing Control Centers, operated by individual spaceport users, to control ground processing of flight vehicles
- Central, common, shared-use receiving facility for vertical launch vehicle components
- Receiving facility for super-heavy lift vehicles/components
- Receiving facility for sensitive/secure/hazardous vehicles/components
- Common, shared-use automated adaptable interfaces capable of handling and facilitating assembly of multiple vertical launch vehicles of similar proportion
- Automated adaptable interfaces capable of handling and facilitating assembly of super-heavy lift launch vehicles
- Precision Local Positioning System for vehicle and servicing interfaces (see architecture #2)
- Universal ground transportation/handling system (see architecture #1)
- Processing facilities (see architecture #2)
- Systems within each vehicle/payload processing facility (see architecture #2)
- Spaceport Information Infrastructure (SII) (see architecture #CC1)
- Integrated health Management (IHM) systems (see architecture #CC2)

7 FLIGHT SYSTEM INTEGRATION

Capability Description:

Integration includes joining and interface of major flight system elements (e.g., flight vehicle stages, payloads/cargo with a launch vehicle, etc) and the verification that an integrated flight vehicle system is ready for departure operations. This includes infrastructure and systems for lifting/cranes, positioning and alignment, access, interface support and functional verification of integrated systems integrity.

Top Level Performance Requirements:

- Integrate flight system and payload within minutes to hours
    - Self-aligning, self-guiding, self-verifying positioning systems
        - Automated/autonomous umbilical to facility connections
    - Robotic support for lifting/mating
    - Minimize lifting hazards during integration
    - Standardized interfaces for each commodity
    - Non-hazardous separation systems that do not generate debris
    - IHM with remote/autonomous self-test, fault detection, diagnostics, troubleshooting, checkout
- Cargo (as opposed to an active payload) is self-contained, requiring no services from flight vehicles
- Software modules that automatically recognize and reconfigure based on flight hardware interfaces

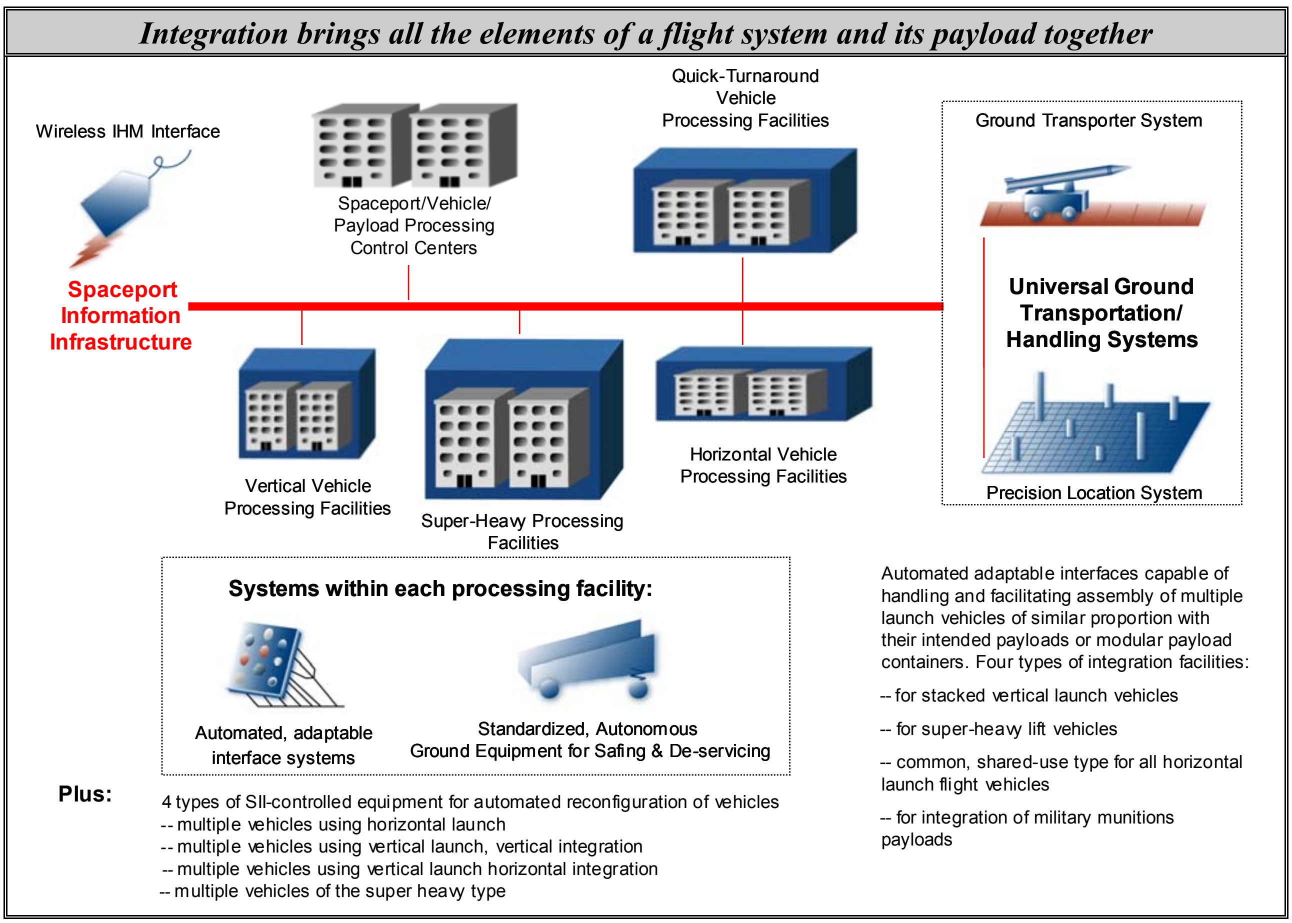


Figure 12 – Flight System Integration Architecture

Description of Architecture:

The Flight System Integration Infrastructure is built up of common, standardized facilities of sufficient size, number, and capacity to accommodate concurrent and off-line operations of multiple vehicle types/architectures.

The detailed elements of the flight system integration architecture include:

- 4 types of SII-controlled insertion equipment for automation-assisted integration of flight vehicle configurations. Facilities provided for the following:
    - Multiple vehicles using horizontal launch
    - Multiple vehicles using vertical launch, vertical integration
    - Multiple vehicles using vertical launch horizontal integration
    - Multiple vehicles of the super heavy type
- Automated adaptable interfaces capable of handling and facilitating assembly of multiple launch vehicles of similar proportion with their intended payloads or modular payload containers. Four types of integration facilities:
    - Common, shared-use type for all horizontal launch flight vehicles
    - Type for stacked vertical launch vehicles
    - Program-specific type for super-heavy lift vehicles
    - Program-specific type for integration of military munitions payloads
- Universal ground transportation/handling system (see architecture #1)
- Processing facilities (see architecture #2)
- Spaceport Information Infrastructure (SII) (see architecture #CC1)
- Integrated health Management (IHM) systems (see architecture #CC2)

8 CREW & PASSENGER

Capability Description:

This is the infrastructure and operations that prepare flight crew and passengers for their voyage. Systems provide for Crew & Passenger arrival, queuing, and ingress into flight system vehicles. These operations may also need to accommodate passengers and crew egress from vehicle elements newly returned from flight. Also included are the routine servicing and maintenance of support equipment uniquely associated with human space flight.

Top Level Performance Requirements:

- Less than TBD incident rate for space vehicle passengers & crew within the spaceport area of operation
- Departing Passengers ready for boarding within TBD hours of entry to the spaceport
- Arriving Passengers ready for exit from the spaceport within TBD hours of landing at the spaceport
- Enable vehicle Crew/Passenger systems (ECLSS) servicing/turnaround within TBD hours of landing at the spaceport

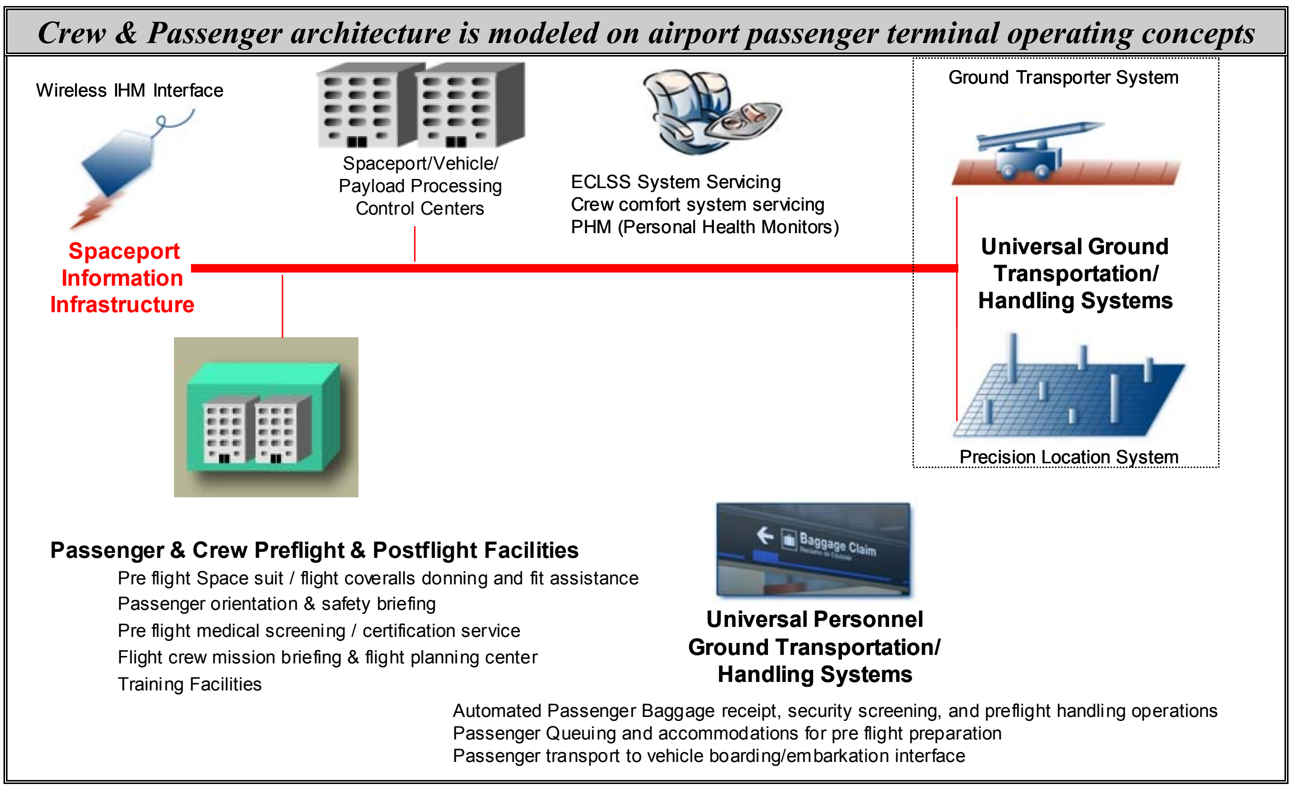


Figure 13 – Crew and Passenger Architecture

Description of Architecture:

The Crew and Passenger Infrastructure provide support for the flight crews (astronauts) of current space flight systems as well as evolving accommodation of the passengers that will increasingly need facilities in the 3rd era.

The detailed elements of the crew and passenger architecture include:

- Universal personnel ground transportation/handling system
    - Automated Passenger Baggage receipt, security screening, and preflight handling operations

    - Passenger Queuing and accommodations for pre flight preparation
    - Passenger transport to vehicle boarding/embarkation interface
- Passenger & crew preflight preparation facility
    - Pre flight Space suit / flight coveralls donning and fit assistance
    - Passenger orientation & safety training systems
    - Pre flight medical screening / certification service
    - Flight crew mission briefing & flight planning center
    - Training & certification systems for flight operations personnel
- Passenger and crew postflight receiving facilities
    - Postflight recovery/adaptation to 1G equipment
    - Postflight Medical checkup systems
    - Medical emergency treatment systems
    - Flight crew mission debriefing center
- Customs secured area for international travelers
- ECLSS System Servicing
    - Automated Post flight waste tank(s) drain & sterilization equipment
    - Breathing air tanks recharging system
    - CO2 scrubber system cartridge exchange/replenishment
    - On-Board coolant fluid servicing/replenishment
    - Post flight Space suit / flight coveralls laundering & servicing
- Crew comfort system servicing
    - Galley post flight cleaning & servicing
    - In Flight food & drinking water supply replenishment
    - Passenger cabin cleaning & servicing
- PHM (Personal Health Monitors)
    - Passenger, flight crew and ground crew screening and access control

   - Provide appropriate biomedical monitoring interface capability for flight crew and passengers as required during ground operations
   - Provide real-time location information for all personnel in operations areas for safety accounting and security purposes

- Ground-side space tourism facilities
   - Accommodations for family and friends of passengers
   - Systems and equipment for Communication with travelers
- Universal ground transportation/handling system (see architecture #1)
- Spaceport Information Infrastructure (SII) (see architecture #CC1)
- Integrated health Management (IHM) systems (see architecture #CC2)

9 DEPARTURE OPERATIONS

Capability Description:

Departure is the infrastructure and systems that support final propellant servicing and launch of flight vehicles. This includes systems providing for structural/physical support, sound suppression, runways, access/environmental concerns, launch assist systems and any other systems directly involved with vehicle flight origination.

Also included here are Ground systems turnaround encompassing post-departure recycling and servicing of ground-based systems supporting flight operations. This function includes active safing systems, wash downs, replenishment of volatile commodities, reloading of imaging support systems, etc. These are the routine, scheduled activities involved in the normal cycle of operations.

Top Level Performance Requirements:

- Execute departure operations within minutes/on demand, including propellant servicing and verification of flight readiness
   - Spaceport traffic integrated with NAS, space traffic control
   - Dozens (or fewer) versus hundreds of console operators
   - On-demand propellant loading systems with rapid chill-down capability, as required, and automated umbilicals
   - Sufficient capacity to support concurrent operations, including hazardous ops
   - On-board control of preflight checkout and servicing with minimal, automated ground support

- Sufficient land area to enable moving vehicles into and out of queue as needed
- Highly reliable ground equipment
- Passive/active noise abatement

- Continuous command & control of the payload, not through the Range
- Crew/passenger boarding minutes from takeoff
- Safe separation systems that don't generate debris
- Leak Management systems to detect potential hazards
- Automated process control with learning systems
- Ability to operate in TBD% of weather conditions
- Management of departure traffic is seamlessly integrated with NAS, orbital collision avoidance, space traffic control
- Clean pad and runway
- Automated Final checkout and servicing
- Continuous health monitoring
- Standardized command/control systems
- Departure traffic management seamlessly integrated with orbital insertion and beyond
- Standardized, simple, integrated decision process and tools
- Restore and re-service ground systems for reuse within minutes to hours
- Informed maintenance based on IHM data
- Automated clean-room maintenance
- Modifications/updates are done through software

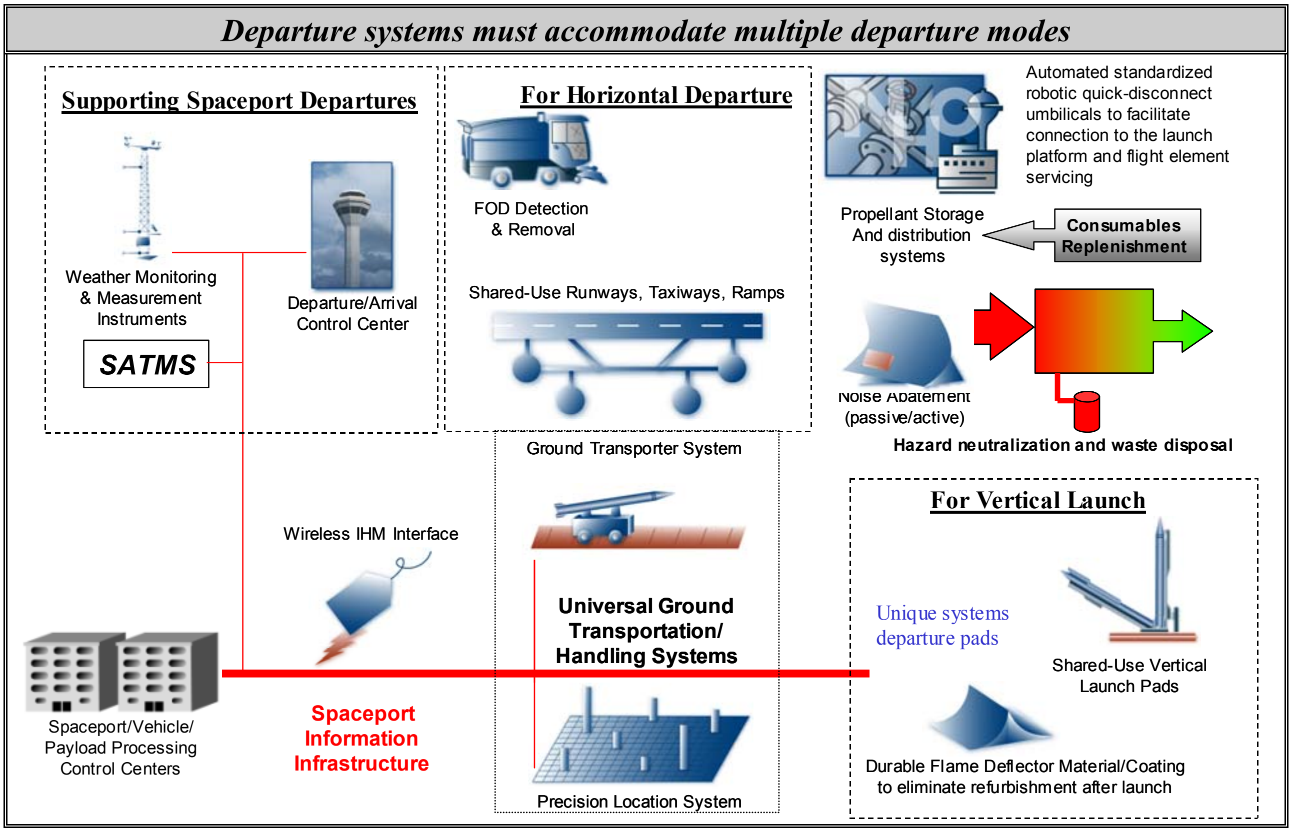


Figure 14 – Departure Architecture

Description of Architecture:

The Departure Infrastructure is built around the concept of Universal Departure points, that is, shared launch pads and/or runways. The architecture envisions 4 types of launch facility configurations:

- Clean pads with minimal fixed infrastructure for shared use by multiple vertical launch vehicle operators
- Launch pads with fixed infrastructure for vertical launch vehicles
- Launch pads with extensive infrastructure for super-heavy lift vehicles
- Runways with crosswind/all-weather capability for horizontal takeoff vehicles

The detailed elements of the departure architecture include:

- Automated standardized robotic quick-disconnect umbilicals to facilitate connection to the launch platform and flight element servicing
- Automated Fueling / Servicing System

- Automated / Robotic Umbilicals
- Smart QD's
- Self-verifying Interfaces
- Propellant Storage & Distribution Infrastructure
- Intelligent Safing & Revert

- Adaptable platforms/ramps for vehicle ingress by crew and passengers
- Precision Local Positioning System for vehicle access, processing equipment, vehicle elements, and servicing interfaces (see architecture #2)
- Passive/active noise abatement and Blast Mitigation system
- Automated FOD Detection & Removal
- Launch Control is a User Function - facilitated through the Spaceport control center
- Launch abort, recycle, and crew emergency evacuation systems
- Ground Systems Restoration
    - Spaceport Information Infrastructure to provide data and communication connectivity among all automated systems
    - Systems and equipment to service, maintain, modify/modernize, and restore ground systems, such as commodity replenishment, maintenance and refurbishment of flame duct and pad area after a vertical launch
    - Precision Local Positioning System for GSE (see architecture #2)
    - Self-cleaning Pad
        - Hazard neutralization system
        - Waste Disposal
    - Commodity Replenishment
- Universal ground transportation/handling system (see architecture #1)
- Spaceport Information Infrastructure (SII) (see architecture #CC1)
- Integrated health Management (IHM) systems (see architecture #CC2)

10 SPACEPORT SUPPORT SERVICES

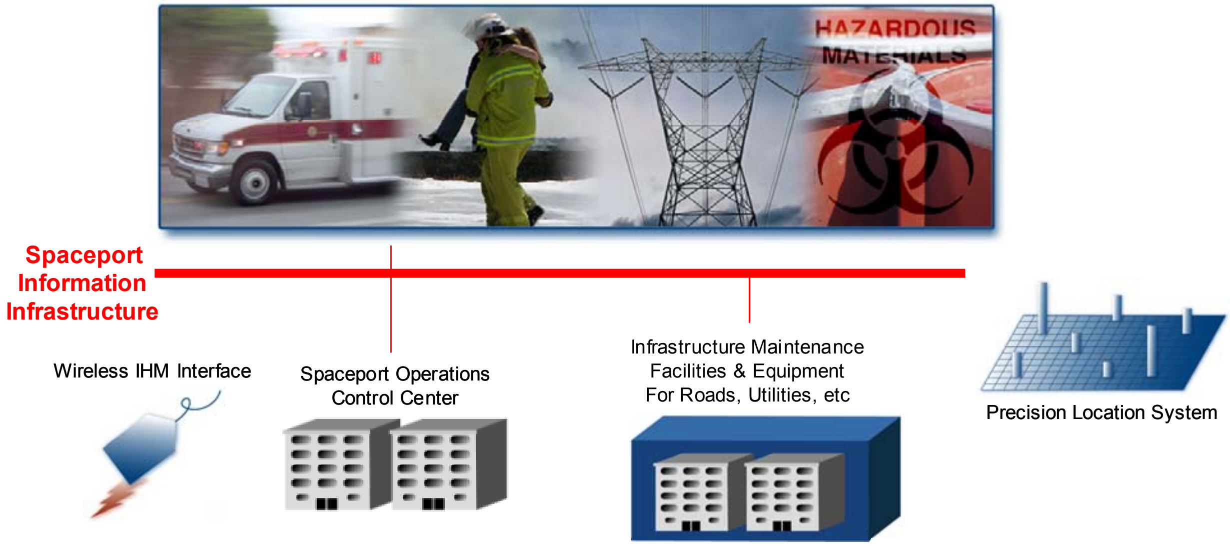
Capability Description:

Shared support services provided to operators and customers through facilities, equipment and infrastructure. These services provide general, commonly used capabilities for spaceport users/customers. This function includes roads, plumbing, power, fire/rescue, security, office space, food/concessions, etc.

Top Level Performance Requirements:

- Reuse/recycle waste streams to prevent impact to ongoing operations
- Co-generation—integrated utility and propellant capabilities
- Systems approach to production, storage, distribution
- Utility system maintenance based on trend analysis to maximize availability
- Automated security systems, autonomous response, integrated access control
- Autonomous emergency detection and response to fire, medical, hazardous material spills, etc

Shared services are the main business of spaceports



- Concessions, overnight accommodations, training, equipment issue and medical services and security.
- Crew facilities would be similar with some services combined for crew and passengers.
- Perimeter security and monitoring systems, access control systems, facilities for security patrol forces
- Fire and emergency response facilities and equipment
- Emergency medical facilities and equipment
- Utilities: electrical power distribution, water distribution, sewer/waste water treatment
- Explosive storage facilities (e.g., bunkers) for pyrotechnic devices, ordnance, etc
- Hazardous waste storage and handling

Figure 15 – Support Services Architecture

Description of Architecture:

The Support Services Infrastructure provides all of the day-to-day services and equipment of the spaceport for its users, tenants and operators. The pooling of these resources provides an economy of scale for overall space transportation system affordability.

The detailed elements of the support services architecture include:

- Spaceport Control Center at each spaceport, to coordinate use of spaceport facilities and systems
- Concessions and overnight accommodations for crew, passengers and their guests.
- Training, equipment issue and medical services and security.
- Perimeter security and monitoring systems, access control systems, facilities for security patrol forces
- Fire and emergency response facilities and equipment

- Emergency medical facilities and equipment
- Industrial safety support systems and equipment
- Utilities: electrical power distribution, water distribution, sewer/waste water treatment
- Explosive storage facilities (e.g., bunkers) for pyrotechnic devices, ordnance, etc
- Hazardous waste storage and handling
- Commercial services: such as Copying equipment
- Back shop facilities, calibration and NDE labs
- Transportation infrastructure to facilitate spaceport logistics: roads, bridges, rail lines, ports, canals, airfields, tow-ways
- Precision Local Positioning System (see architecture #2)
- Institutional Support for facility maintenance, telecommunications, HVAC, etc
- On-Site Distribution of consumables (propellants, gases, etc)
- Universal ground transportation/handling system (see architecture #1)
- Spaceport Information Infrastructure (SII) (see architecture #CC1)
- Integrated health Management (IHM) systems (see architecture #CC2)

11 MONITOR & MANAGE THE FLIGHT

Capability Description:

Operations that monitor and coordinate active flight operations that have, can, or will affect the spaceport. Systems actively monitor vehicle and payload flight and mission operations to maintain situational awareness related to the potential need for support from the spaceport operational infrastructure. Operations centers coordinate support in real-time as mission status changes see architecture more detail in the FIRST Space Vehicle Operators CONOPS. Spaceport Control centers coordinate incoming and outbound flight activities and ensure safe and successful mission operations.

Top Level Performance Requirements:

- Spaceport system turnaround within an hour for single-string facilities, real-time (i.e., continuously available) to support concurrent flight operations
- Departure control setup within hours to a day
- Arrival configuration achievable within minutes on an emergency basis

- Mission control separate from but parallel with coordinated traffic control
- Seamless coordination with NAS, space traffic control—"free flight" mode of ops
- Continuous command & control of the payload, not through the vehicle
- In-flight payload data reduction and analysis

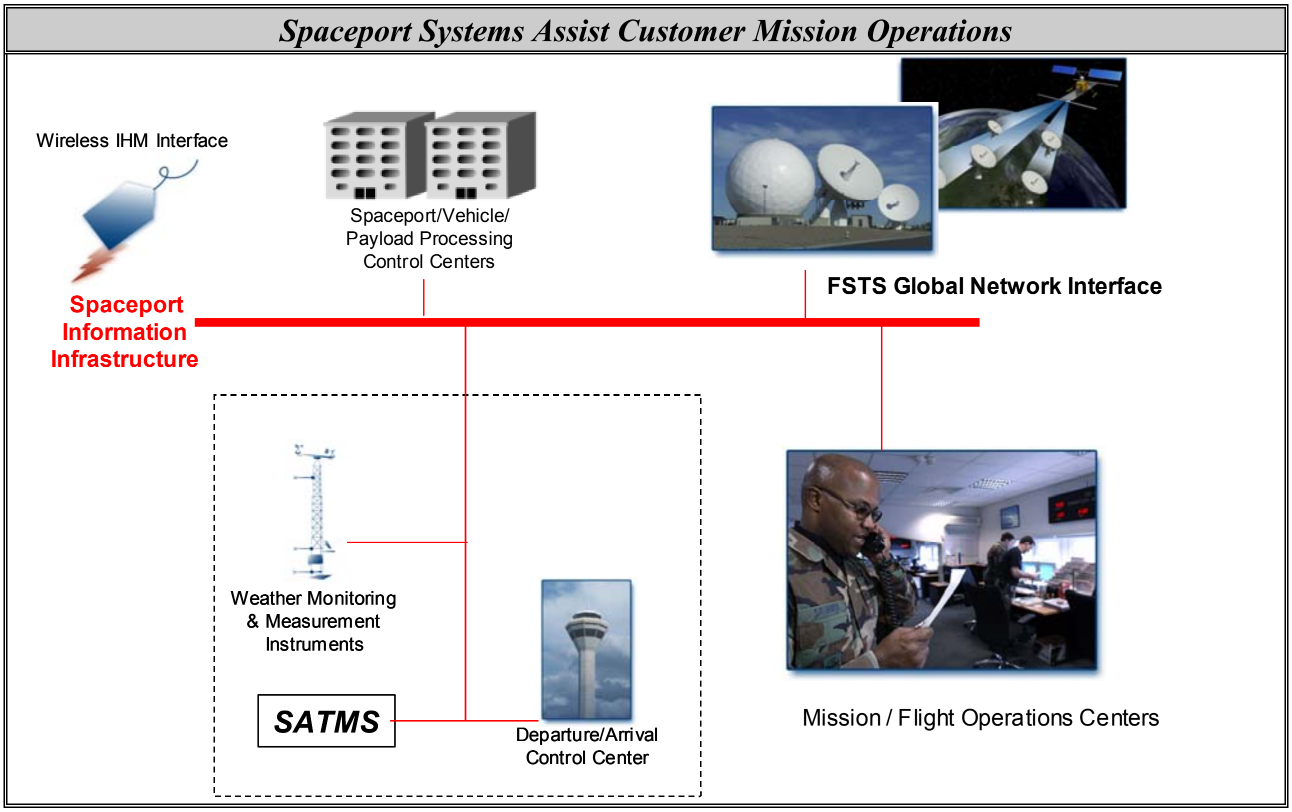


Figure 16 – Monitor & Manage Flight Architecture

Description of Architecture:

The Monitor and Manage Flight Infrastructure provide data and real-time communication for support of flight operations and associated Control Centers being operated at a spaceport. The foundation of this architecture is the common, shared-use Departure/Arrival Control Center facility for the spaceport to passively monitor missions that could potentially require spaceport support on a short-notice emergency basis

The detailed elements of the Monitor and Manage Flight architecture include:

- Local Weather / Environmental / Spaceport Status & Availability systems reporting to the Global Network
- Liaison support systems for mission/customer teams
- Infrastructure to support tenant operations control centers

- Personal communications terminals and systems for ground-based participants in space tourism

  - Spaceport Information Infrastructure (SII) (see architecture #CC1)

  - Integrated health Management (IHM) systems (see architecture #CC2)

12 GROUND TRAFFIC CONTROL

Capability Description:

Ground Traffic Control relies on vehicle and ground system hardware, software, wiring/cable, fiber optics, and wireless transmission capabilities to monitor, coordinate, and control surface movement of flight vehicle elements, payload elements, spaceport equipment, and general vehicular traffic within the spaceport environment. This includes central control and monitoring of spaceport facilities and systems to ensure proper configuration, current calibration, proper operation, maintenance needs, etc to ensure readiness to support scheduled ground and flight movement operations.

Top Level Performance Requirements:

- Less TBD incident rate in spaceport ground movement operations

- Ground movement approval within minutes of request

- Automated de-confliction of concurrent ground movement operations within the spaceport for flight elements, ground support equipment, payload transporters, and other local surface traffic at the spaceport

- Ground pathway clearance for emergencies achieved within minutes of alert

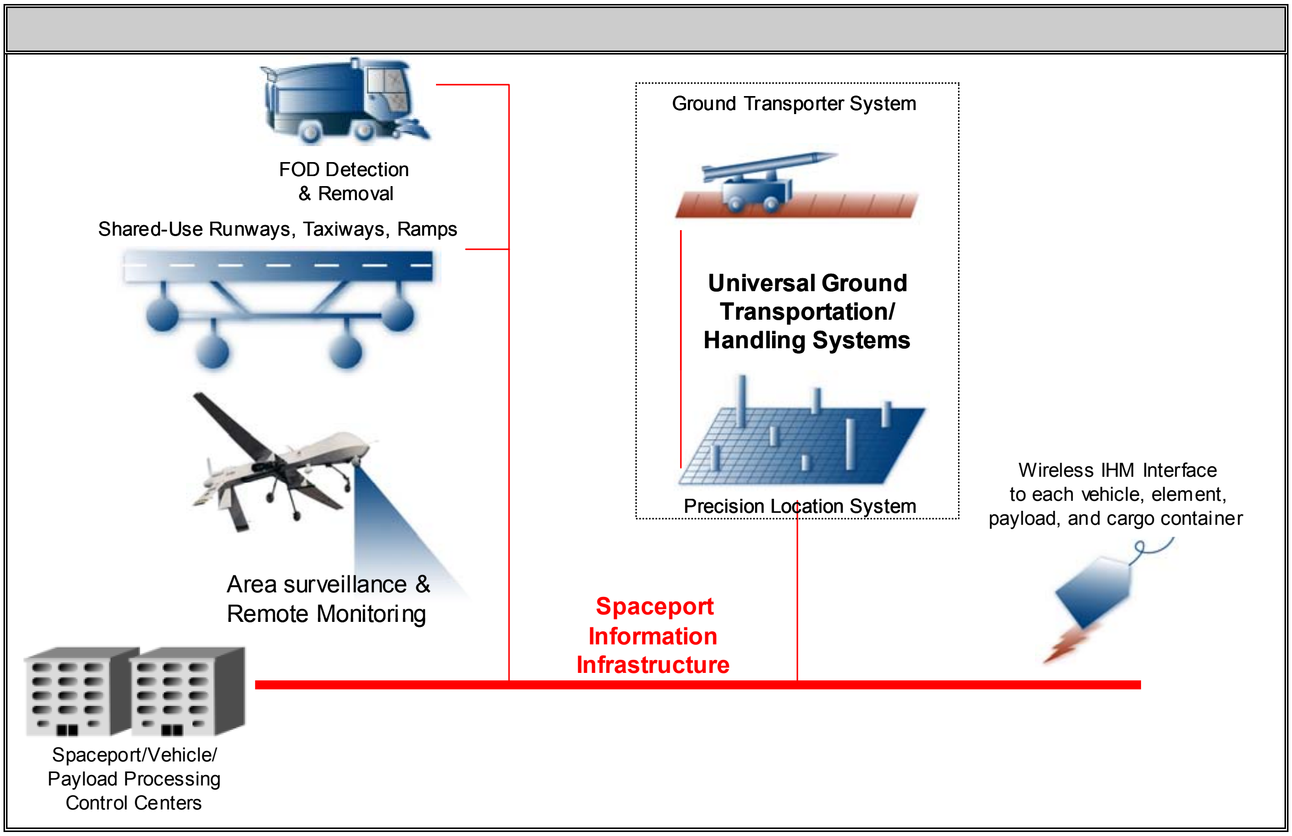


Figure 17 – Ground Traffic Control Architecture

Description of Architecture:

The Ground Traffic Control Infrastructure provides positive control and coordination of ground movement within the “airside” operations areas of the spaceport. This function is implemented primarily at the Spaceport control center that is the central coordination and clearinghouse for ground movements.

The detailed elements of the ground traffic control architecture include:

- Spaceport traffic surveillance & remote pathway monitoring equipment
- Ground/landside traffic management systems
- Intermodal transportation interface assistance systems
- Alternative ground movement/pathway technology systems
- Inclement weather protection systems
- Precision Local Positioning System (see architecture #2)
- Automated FOD Detection & Mitigation systems

- Universal ground transportation/handling system (see architecture #1)
- Spaceport Information Infrastructure (SII) (see architecture #CC1)
- Integrated health Management (IHM) systems (see architecture #CC2)

13 SPACEPORT LOGISTICS & ENGINEERING

Capability Description:

Logistics provides the facilities and hardware/software systems that support daily spaceport and range operations as well as sustaining engineering support. This includes storage, cleaning, for commodities, supplies, spare parts, ground systems, tools, protective clothing & equipment, precision measuring equipment, and other support equipment required to enable the safe and efficient conduct of ground processing activities. It also includes the engineering systems for sustained operations of the FSTS such as mission planning systems, office space, documentation preparation, training & certification development, configuration management and other related aspects of sustaining engineering.

Top Level Performance Requirements:

- Delays in only TBD transactions
- Paperless procedures available on heads-up displays, automated records of completion
- Reconfigurable test equipment
- Fault isolation and retest accomplished by IHM systems
- One person, one tool, one minute, to do one repair
- Automated and centralized, integrated inventory, parts ordering, procurement, receiving, inspection, storage systems (dock to stock to issue)—integrated with vendors—and with continuous asset tracking and collection of metric data regarding parts performance to support predictive maintenance approach
- Lossless consumables transfer (e.g., no boil-off of cryogenic fluids)
- Minimize need for special tools, equipment—maximize shared-use common support systems
- Standard models for design of shared-use common facilities and equipment, designed for easy upgrades and scalability

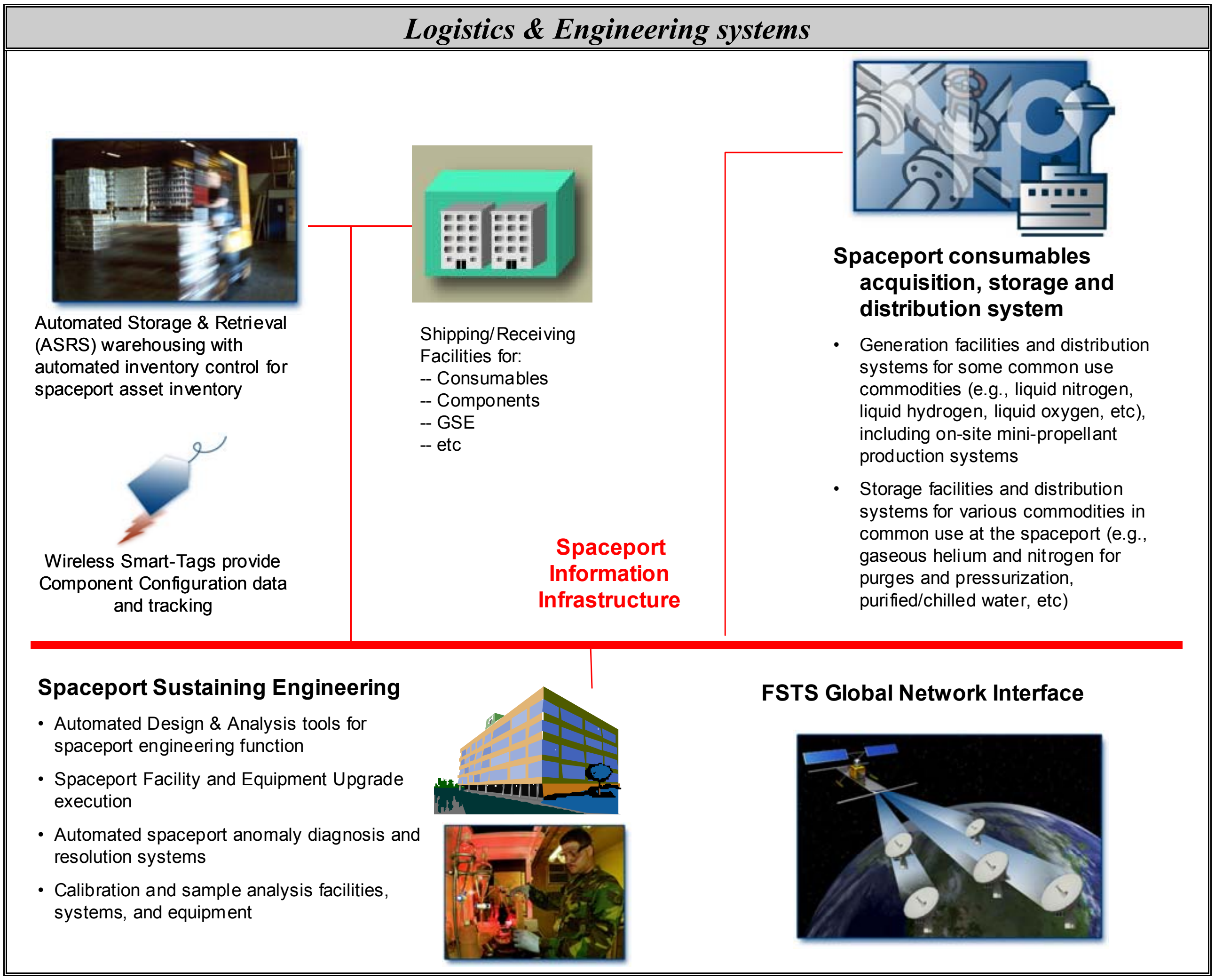


Figure 18 – Logistics Architecture

Description of Architecture:

The Logistics Infrastructure is a key element of spaceport operations.

The detailed elements of the Logistics architecture include:

- Automated Informed Maintenance (AIM) systems for interval scheduling and optimization of maintenance planning (see architecture #5)
- Automated Storage & Retrieval (ASRS) warehousing with automated inventory control for spaceport asset inventory
    - Consumable Parts
    - Spare Parts
    - Tools

- Precision Local Positioning System
  - Provides total spaceport inventory management information
  - Real-time tracking and status of all spaceport assets
- Spaceport workforce Certification & Training systems
  - Wireless advanced Personal IT Platforms (PIPs) with hands-free operation provide an interface to the SII and its AI database to provide vehicle specifications, diagnostic analysis and support, and recommended service procedures for technicians
  - Training facilities, activities & certifications
- Spaceport Sustaining Engineering systems
  - Infrastructure life-cycle planning
  - Automated Design & Analysis tools for spaceport engineering function
  - Work control systems for Spaceport Facility and Equipment Upgrades
  - Automated spaceport anomaly diagnosis and resolution systems
  - Calibration and sample analysis facilities, systems, and equipment
- Spaceport consumables acquisition, storage and distribution system
  - Generation facilities and on-demand distribution systems for commonly used consumables (e.g., liquid nitrogen, liquid hydrogen, liquid oxygen, etc), including on-site propellant production systems
  - Storage facilities and on-demand distribution systems for various consumables in common use at the spaceport (e.g., gaseous helium and nitrogen for purges and pressurization, purified/chilled water, etc)
- Universal ground transportation/handling system (see architecture #1)
- Spaceport Information Infrastructure (SII) (see architecture #CC1)
- Integrated health Management (IHM) systems (see architecture #CC2)

14 MANAGEMENT & COMMUNITY

Capability Description:

Management of spaceport assets involves Planning, scheduling, and coordination hardware and software that provide de-confliction and scheduling of all internal/external spaceport assets, as well as coordination necessary to meet flight mission requirements. These systems can be used to draw conclusions and modify processes as a result of comparing actual versus scheduled and tasks, situational awareness information leading up to decision points, resource availability, and safety constraints. Analysis and learning functions also include assessing trends based on schedules and work performance and providing recommendations to generate new or modified work instructions to incorporate lessons learned.

Spaceports interact with other transportation types (Air, Sea, and Overland) and their surrounding Community. Interfaces include utilities, communications, economics, public relations, health & safety, employment, etc.

Top Level Performance Requirements:

- Master planning function with rolling 5-7 year infrastructure needs forecast
- Seamless interface with local and regional transportation network
- Real-time hazard warnings to affected community emergency operations centers

Description of Architecture:

The Management and Community Infrastructure is the essential element of spaceport operations, planning and integration within its surrounding community. The architecture is heavily intertwined with the SII and provides most of its services to customers through a network-based customer interface.

The detailed elements of the Management and Community architecture include:

- Spaceport Management systems
    - Spaceport Control Center at each spaceport, to coordinate use of spaceport facilities and systems
    - Spaceport Information Infrastructure to provide data and communication connectivity among all automated systems Information Management Systems
- Spaceport operations Standards office
    - Environmental Compliance
    - Practices and Procedures
- Customer Services office
    - Single, centralized point-of-contact for spaceport services
    - Simplified customer interface (TurboTax-like) for spaceport service requests
- Business Planning /Executive Management systems
    - Use of Expert Systems for Decision Support

- Streamlined Management team
- Master planning, environmental protection, planning for/with-surrounding communities, affects of future spaceport development & mitigation efforts via planning such as over flight activity increase, noise increase and mitigation

- Contracts and Financial Management systems
  - Budget management, requisition/purchasing & cost control/budget adherence
- SII– Public / Community Interface
  - Interface to Internet
  - Interaction with Emergency Operations Centers
  - Modeling Emergency Response & Coordination
- Multi-Modal Transportation Interface
  - Coordination with local & regional surface traffic planning & control organizations
  - Establish sea / air transportation corridors coordinated with regional authorities and designed for minimal interference with spaceport operations
  - Maximize use of established multi-modal standard carriers (containers) for spaceport shipping & receiving
- Community Outreach systems
  - Public relations office
  - Educational outreach programs office
  - Viewing stands where public visitors can view spaceport activities/launches/flights
  - Information displays and visitor centers featuring historical artifacts, information on current mission activities and evolutionary technologies

CROSS-CUTTING CONCEPTUAL ARCHITECTURE DESCRIPTIONS

CC1 - SPACEPORT INFORMATION INFRASTRUCTURE (SII)

Capability Description:

The crosscutting information management systems architecture provides networking, communications, data storage, data retrieval, data analysis, system monitoring, command & control, remote access, and overall connectivity among all spaceport systems, users, operators and remote clients.

Top Level Performance Requirements:

- TBD Megabytes/second data transfer backbone
- Active and passive knowledge capture from ongoing operations
- Network and comm systems achieve 6 Sigma accuracy rate in all information transfer operations
- 100% system availability for critical operations
- Information security maintained at user, user group and public levels

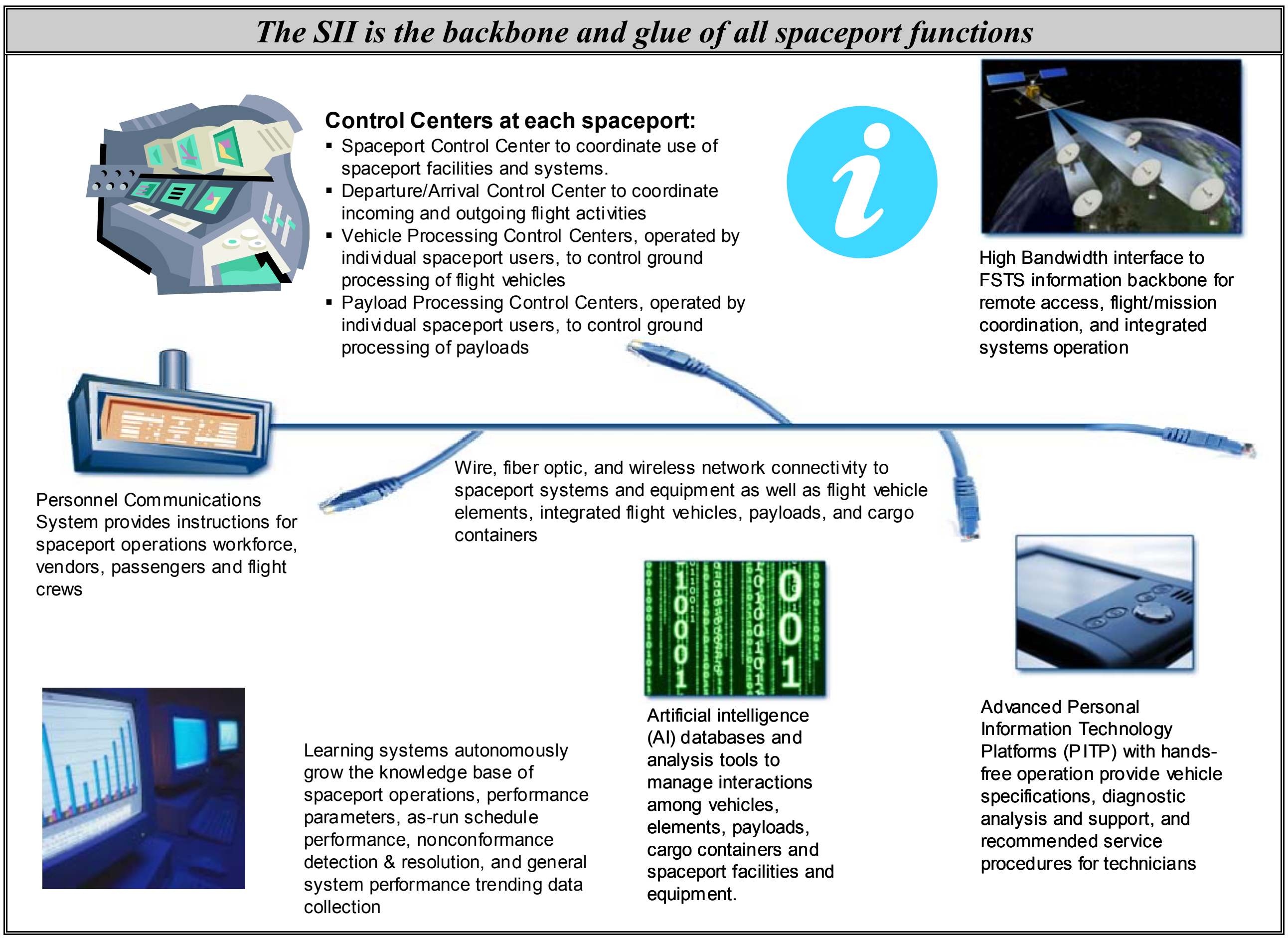


Figure 19 – Spaceport Information Infrastructure

Description of Architecture:

The Spaceport Information Infrastructure provides data and communication network connectivity among all automated flight and ground support systems and Control Centers being operated at a spaceport, and automated decision support tools to speed and simplify operations. The SII is the integrating element of all spaceport systems. It interfaces with all active system elements of the total spaceport enterprise, supporting both spaceport host operations and spaceport user operations.

The SII provides real-time data conduits for control and monitoring applications, transaction processing for customer access to host applications, information logging and retrieval, and broadcast of information to multiple display ports. The SII leverages information systems technology with special emphasis on low-power, handheld, and wearable interface technology.

The detailed elements of the SII architecture are:

- Wire, fiber optic, and wireless network connectivity to spaceport systems and equipment as well as flight vehicle elements, integrated flight vehicles, payloads, and cargo containers.

- Control Centers at each spaceport:

    - Spaceport Control Center to coordinate use of spaceport facilities and systems.

    - Vehicle Processing Control Centers to control ground processing of flight vehicles

    - Payload Processing Control Centers to control ground processing of payloads

    - Departure/Arrival Control Center to coordinate incoming and outgoing flight activities

- Artificial intelligence (AI) databases and analysis tools to manage interactions among vehicles, elements, payloads, cargo containers and spaceport facilities and equipment. These tools provide:

    - Automated scheduling and de-confliction within constraints imposed by resource loading profiles for facilities, equipment and crews, based on needs as generated by schedule requests through the network, and IHM systems aboard flight vehicles, flight vehicle elements, payloads, cargo containers, and ground support equipment.

    - Requirements and arrangements for emergency stand-by support services, including for example, fire, toxic clean up and medical support.

    - Coordination for use of National Airspace System (NAS) and space transition corridors through the Space and Air Traffic Management System (SATMS).

    - Management of automated ground movement systems throughout the spaceport

- Management of robotic handling and servicing equipment controlled through the SII using pre-programmed instructions along with artificial intelligence analysis tools
- Supply Chain Management and spare parts / commodity needs analysis using automated interfaces to logistics ordering, processing, delivery, and staging systems for commodities, parts and tools to support ground operations.
- Connectivity to automated parts-ordering system, tool placement/delivery, automated inventory control system
- Management of support for assisted maintenance and repair functions where human interface is required

- Personnel Communications System provides instructions for spaceport operations workforce, vendors, passengers and flight crews
- Interfaces to IHM systems to support integration with the spaceport's automated logistics systems.
- Central database of Technical Documentation for on-line, real-time training and records of test/checkout/repair procedures, as executed.
- Advanced Personal Information Technology Platforms (PITP) with hands-free operation provide an interface to the SII and its AI database to provide vehicle specifications, diagnostic analysis and support, and recommended service procedures for technicians
- Learning systems which autonomously grow the knowledge base of spaceport operations, performance parameters, as-run schedule performance, nonconformance detection & resolution, and general system performance trending data collection
- High Bandwidth interface to FSTS information backbone for remote access, flight/mission coordination, and integrated systems operation
- Access control to SII through positive user authentication
- Implementation of strong information security to limit access to sensitive, critical and proprietary data to only authorized users (interface security with worldwide security databases and entities)

CC2 - Integrated Health Management (IHM)

Capability Description:

Cross-cutting systems health management architecture providing real-time system status, prognostic performance predictions, failure analysis and identification, maintenance action scheduling and pre-kitting, and system historical operating knowledge base expansion for spaceport infrastructure, flight vehicle systems, payload systems, and supporting equipment for all spaceport users, operators and remote clients.

Top Level Performance Requirements:

- Provide Prognostic maintenance identification and scheduling for all active spaceport system elements
    - Predict TBD% of all system failures in 2nd era
    - Predict TBD+% of all system failures in 3rd era
- System health & performance knowledgebase enabling greater than 90% learning curve in spaceport system operations
- System performance data and operational history autonomously tracked and recorded for all critical flight, ground, and payload system components

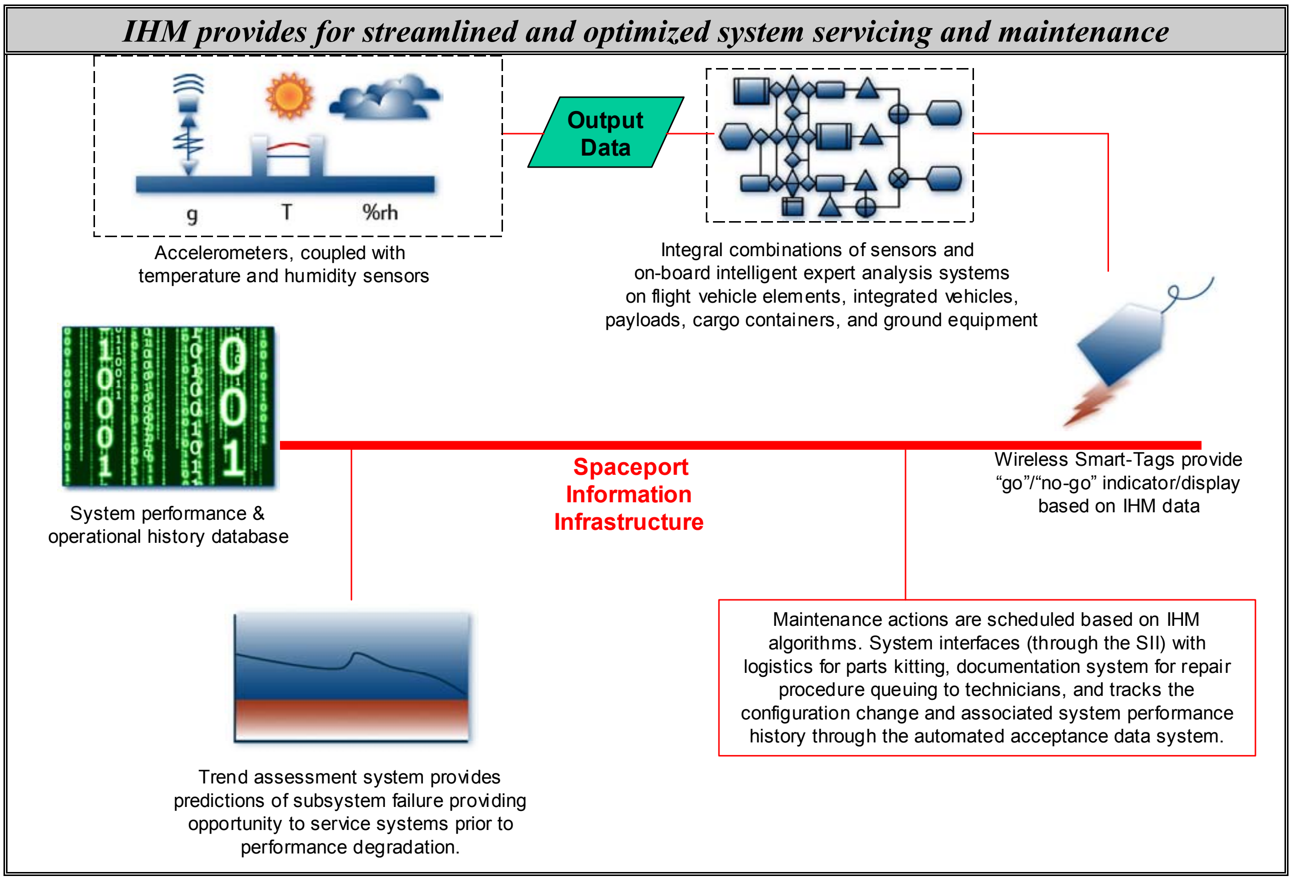


Figure 20 – Integrated Health Management Architecture

Description of Architecture:

The Integrated Health Management Infrastructure provides system health monitoring on flight vehicle elements, integrated vehicles, payloads, cargo containers and ground equipment. The IHM system elements continuously monitor and report on configuration control and real-time system health status by performing remote/autonomous self-test, fault detection/isolation, diagnostics, troubleshooting, checkout, and retest after any change in system configuration or integrity.

The detailed elements of the IHM architecture include:

- Integral combinations of sensors and on-board intelligent expert analysis systems that provide real-time autonomous verification whether flight systems are performing as intended. Provides real-time autonomous verification whether items have arrived at the spaceport facilities ready to fly, based on (i.e., verify acceptable environments and integrity since factory testing and closeout).

- Accelerometers, coupled with temperature and humidity sensors, to continuously monitor the environment flight hardware has been exposed to during transportation to (or between facilities at) the spaceport. These systems simplify receiving and inspection by making it obvious whether system integrity has been maintained since factory testing and closeouts were completed. These systems support decisions whether it will be necessary to do anything more than remove the items that were installed for shipping.

- Sensors coupled with intelligent expert systems, to monitor performance during flight and automatically communicate maintenance and logistics information to the spaceport to simplify routing, logistics, and maintenance schedules and activities.

- Wireless, active Radio Frequency Identification Device (RFID) Smart-Tags provide "go"/"no-go" indicator/display based on IHM data.

- System performance data collection and trend assessment system provides predictions of subsystem failure providing opportunity to service systems prior to performance degradation.

- Maintenance actions are scheduled based on IHM algorithms. System interfaces (through the SII) with logistics for parts kitting, documentation system for repair procedure queuing to technicians, and tracks the configuration change and associated system performance history through the automated acceptance data system. The AIM/ACCMS project could provide a good starting point for this system.

- Redundancy in the Spaceport infrastructure is provided for all critical systems through application of smart-structures, self-healing active systems, autonomous transfer to backup subsystems, and similar technologies which minimize the requirement for man-in-the-loop actions.

Taken together, the two crosscutting architectures touch on all aspects of Spaceport operations.